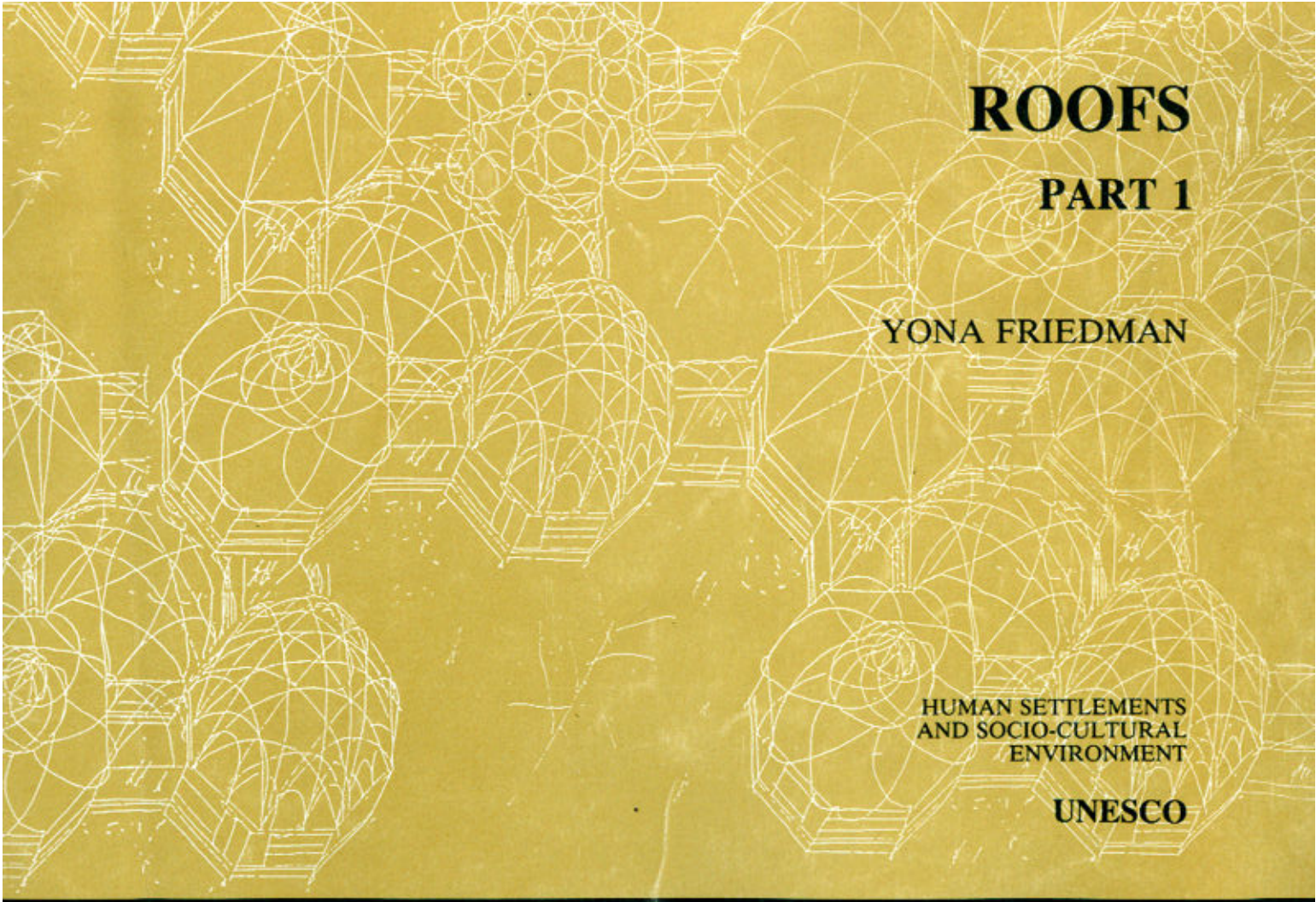


The background of the cover is a dense, intricate line drawing in a light tan color on a darker tan background. The drawing consists of numerous overlapping geometric shapes, including circles, squares, and polygons, which are interconnected by thin lines. These shapes resemble stylized architectural elements, such as domes, vaults, and structural frames, creating a complex, web-like pattern that suggests a global or interconnected theme.

ROOFS

PART 1

YONA FRIEDMAN

HUMAN SETTLEMENTS
AND SOCIO-CULTURAL
ENVIRONMENT

UNESCO

LOCAL MATERIALS, SIMPLE TECHNOLOGY, SOPHISTICATED IDEAS

44

ROOFS

PART 1

YONA FRIEDMAN

**HUMAN SETTLEMENTS
AND SOCIO-CULTURAL
ENVIRONMENT**

UNESCO

Habitat Scroll of Honour 1992 (UNCHS)



COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

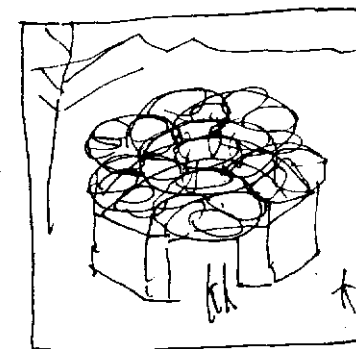


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BD GARIBOLDI, 75015 PARIS ☎ (331) 783-20-24

ROOFS

MADE WITH VEGETAL MATERIALS



THIS WORK WAS CARRIED OUT WITH
A GRANT FROM THE INTERNATIONAL
DEVELOPMENT RESEARCH CENTRE, OTTAWA,
CANADA

The manuals in this collection have been conceived in order to make simple roof-building techniques available to people who have little education and almost no resources. Thus, the techniques presented here are appropriate for self-help building and make use of inexpensive local materials.

It is for these people and for those who are called upon to assist them in their building efforts, that each technique has been presented in sketch-like, non-technical drawings, with short texts. The drawings can be copied easily, even by those without drawing skills.

Roofs are the main subject of these manuals, since roofs appear to be the most complex part of simple shelter. It is less difficult and requires less know-how to build walls and partitions than to build a roof. Roofs are, in fact, more exposed to all kinds of influences and stress than other parts of a shelter. This is the reason why these manuals do not consider foundations, walls, etc. beyond their functions as a support system for the stability of the roof.

The manuals were primarily prepared for the lowest income people in India, a subcontinent with varied climatic conditions, diversified local resources and a wide range of traditional skills. It was the intention of the authors to describe techniques unknown in certain regions without putting, however, too much emphasis on those techniques which are generally known and widely used. The target groups appear to be more attracted and concerned by proposals concerning innovative techniques.

The material in this collection is presented in five major sections:

1. Generalities
2. Techniques using materials of vegetal origin
3. Techniques using materials of mineral origin
4. Principles of simple engineering
5. Security

An Annex indicates the list of materials relevant to each region of the subcontinent.

A. THE COMPLEX PROBLEM OF HOUSING

"Housing" is more than "shelter" and less than "habitat". Indeed, "shelter" simply constitutes a means of protecting against outside aggression, natural or human. "Housing" represents more than just protection, but provides a framework for living, for a wide set of social as well as self-supporting activities. Finally, "habitat" is again different and involves much more than just "housing": it includes all elements of the environment needed for human existence.

Housing is part of habitat, shelter is part of housing.

Before discussing the problems involved in this project, it seems necessary to define these terms. The project presented here deals with a set of technical elements of housing, but, in order to better understand the choice of solutions, an overview of the "problematique" was necessary.

Housing problems, are not restricted to the poor. The solutions we want to put forward concern all societies. But since we have to set priorities, emphasis was put on techniques accessible for the poor members of society.

The general problems of housing can be classified into three principal domains: that of social, environmental and technical criteria.

B. SOCIAL PROBLEMS

First of all, housing projects should facilitate autonomy and survival. For example, a house depends on outside supplies (water, energy, food, etc) but it should be conceived to remain independent even if those supplies are no longer available. Air, water, heating, etc. can be controlled by sophisticated devices, but it is essential that, when such devices fail, supply and control should be available

through unsophisticated means. Cisterns, windows, etc. are among these means.

Another social problem concerns the financial aspects of building of house. This can either be done in cash or in kind (meaning building by the user himself).

The location of the house appears to represent yet another social aspect, and an important one, as it signified "status", can facilitate economic integration and guarantee security. The solution to this problem and an acceptable distribution of sites is a difficult matter to be dealt with in settlements. This aspect will, however, not be covered in this paper.

C. ENVIRONMENTAL PROBLEMS

A man-made artifact (e.g. a house) on the ground can be considered as representing a major impact on the environment. That impact is not actually restricted to the area covered by the roof, but includes all open spaces which are directly or indirectly part of the house: courtyard, lanes, working areas, etc.

In a broader sense, the impact on the ground includes all areas, even distant ones which serve that particular house (including community services). These include shopping areas, roads, water distribution and collecting systems and, consequently all areas which no longer belong to the natural environment.

Thus larger houses can have less impact than smaller ones, if they are more autonomous. Therefore the impact on the ground largely relates to lifestyle.

Building materials for housing also have an impact on the environment. The provision of building materials often implies large gaps in natural environment (e.g. quarries deforestation). Generally speaking, the gaps resulting from the exploitation of vegetative raw materials can be more easily filled, such as a clearing in a

wood, whereas a quarry remains a hole for ever. Consequently self-renewing materials are preferable, especially those which are renewable in the short-term (i.e. bamboo). The material needed for a bamboo building can be grown on about a sixth of the area needed for a building.

D. TECHNICAL PROBLEMS

All aspects described above converge in fact on one technical problem. Thus, economizing on building materials also means positively reacting to both financial and environmental needs; the stability of a building is linked with its autonomy. The possibilities for self-help construction and consequently self-help maintenance depend largely on the techniques employed.

In conclusion, the project proposed offers technical solutions to the whole "problematique" of the above mentioned social and environmental aspects. Although the project was conceived to be carried out by disfavoured people, all considerations and the corresponding techniques can be applied to the middle class, and even to the rich. In other words, if these techniques are suitable for low-income groups, they should be made available to all income groups. Indeed, bamboo domes could be used as a technique for both houses and palaces.

The technical solutions presented in this project concern roofs alone (with a few general topics of simple engineering added). Roofs are the most important and, technically speaking, the most complex elements of buildings. They are an essential part of shelter.

If "habitat" means "food plus roof", the manuals presented cover half the habitat problem.

E. THE WAY THE TOPICS WERE SELECTED

There are many techniques used in the building of a roof: in the selection that follows, the considerations exposed above were used as guidelines.

The first principle is related to the choice of the building material. The concept of "local material" is too vast: they include both natural and artificial materials. Plastics, cardboard or industrial fallout are, in a way, also local materials. Natural materials can be renewable or not. Some of them can be grown easily on a small area, others grow slowly and immobilize large plots for a long period.

In this paper, priority has been given to materials of natural origin. We preferred bamboo, a fast growing plant which occupies less surface area than the building for which it is used. Wood was considered only when absolutely necessary (e.g. pillars), or in cases where scrap wood was used.

Reeds and grass bundles which can be used for interesting roof structures are also mentioned.

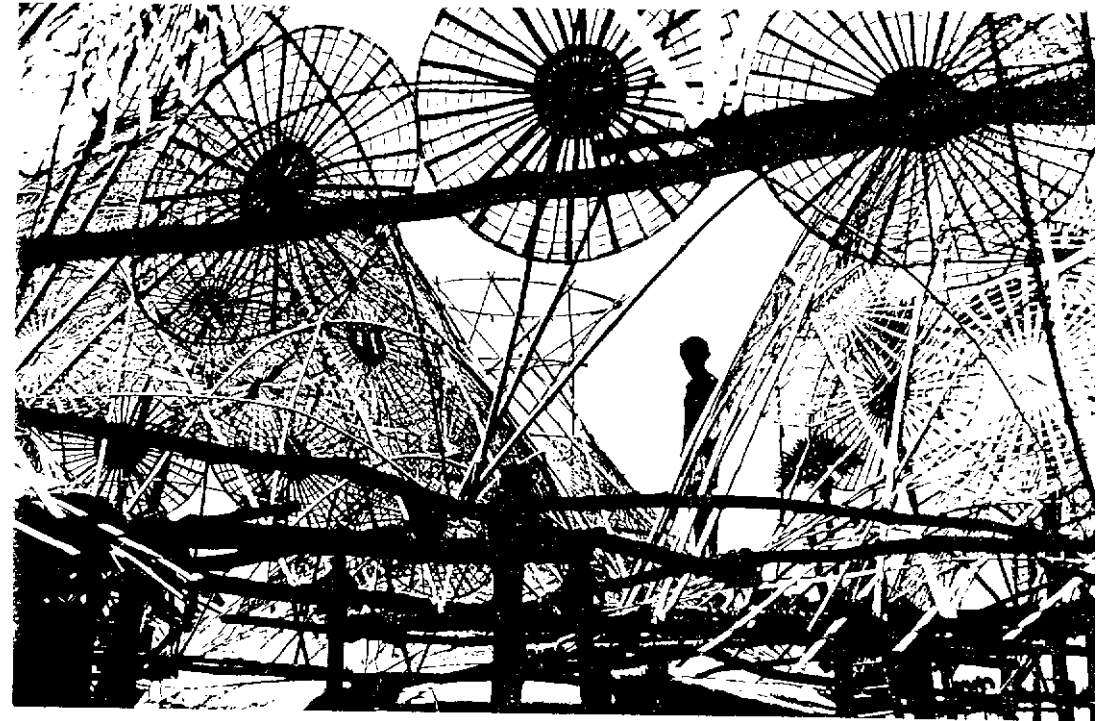
Techniques using mineral resources were restricted to sunbaked bricks. The techniques used to produce them are among the least harmful to the environment.

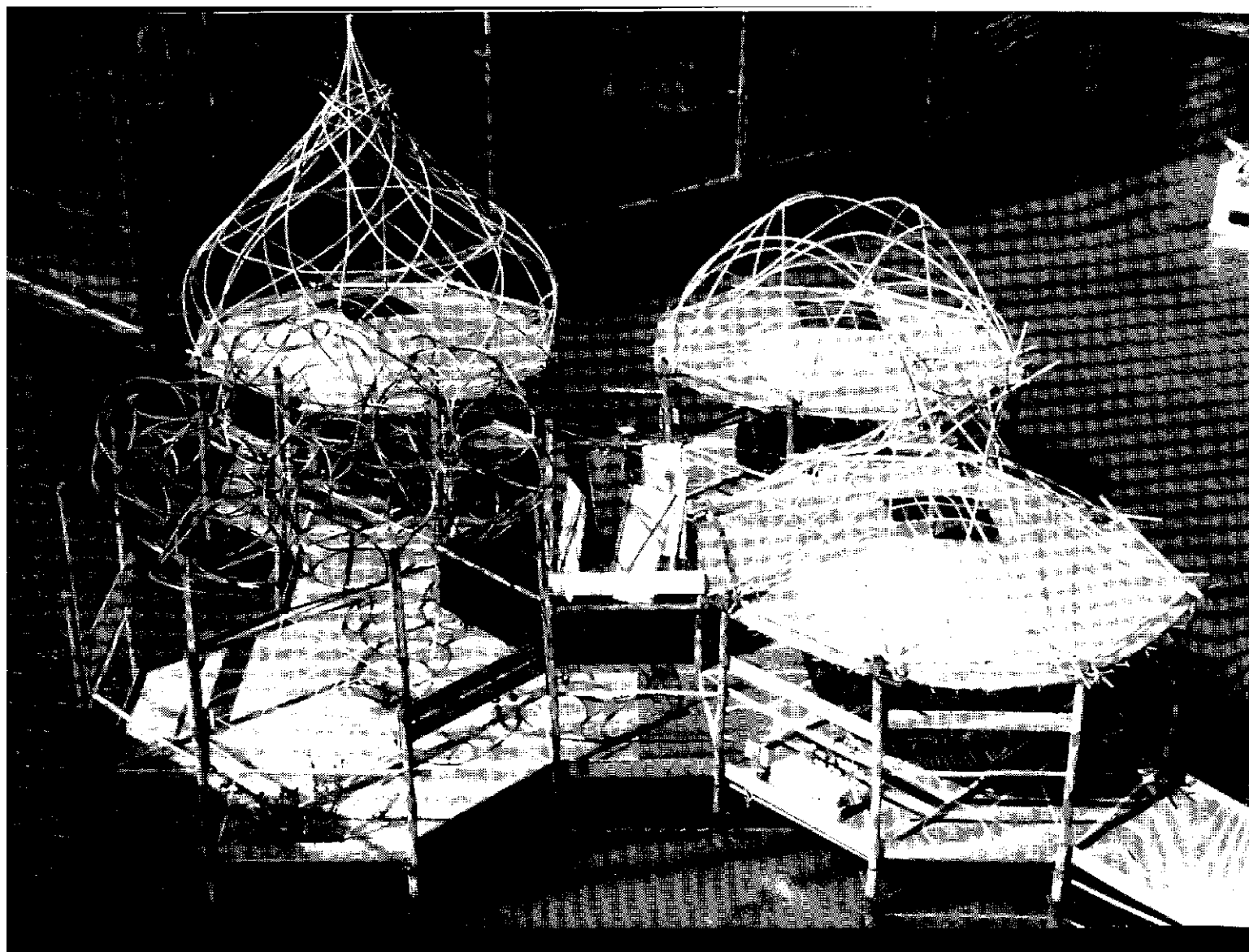
Emphasis was put on roof structures: structures of a reasonable span (4-8 meters), supporting a light-weight roof skin (except in the case of brick domes). The roof skin is composed of sophisticated materials with locally available materials. Bamboo mats, cardboard, etc. are materials used in most shanty towns (and also in many palaces). These materials, combined with waterproof and heat reflecting materials (i.e. aluminium or plastic foil) can guarantee a decent shelter.

Another important criterion is the adaptability of the chosen techniques to self-help building. Thus, the selected techniques should be easy to handle for lay men with simple tools. They involve very little cash investment, and are time-saving. In a few test constructions, it was shown that people having no professional experience in that field, can do the job.

Some of the elements used in building the roofs (mats, rings, bundles) constitute a sort of "village representation", performed by ordinary craftsmen. The same is true for sunbaked bricks or other ceramic components (jars, etc). Obviously all these techniques could be used for industrial production if appropriate finance is available.

The characteristics of the project are simple "cartoon type" manuals conceived for use by a public of potential self-help builders and local craftsmen. Another criterion for the selection of techniques was their adaptability for easy communication. The techniques chosen are easily explained and understood by the target public, whether literate or not. And all this with a few cartoons which look very simple and rough, but which are, in fact, very sophisticated.







MAKING YOUR HOUSE

p. 11



WHAT CAN YOU BUILD WITH
AND HOW?

p. 19



CHOOSING MATERIALS

p. 27



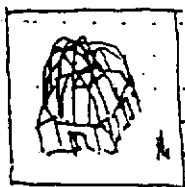
FLAT ROOFS

p. 35



SPACE FRAMES

p. 45



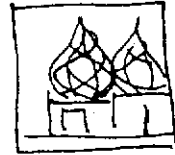
BAMBOO DOMES
WITH SUSPENDED MAT COVER

p. 51



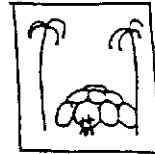
LATTICE DOMES

p. 71



BULB-SHAPED DOMES

p. 75



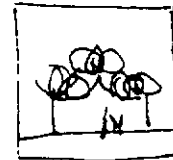
RINGS INTO ROOFS

p. 81



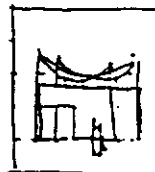
STRUCTURES
MADE WITH RING-BALLS

p. 89



ROOFS MADE WITH RINGS
(SPACE-CHAINS)

p. 101



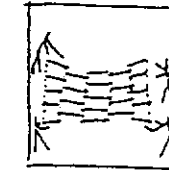
SUSPENDED ROOFS

p. 107



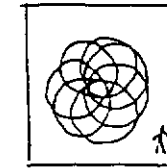
ROPES AND RODS

p. 113



FREELY SHAPEABLE ROOFS

p. 121



DOMES STRUCTURES
WITH FLEXIBLE MATERIALS

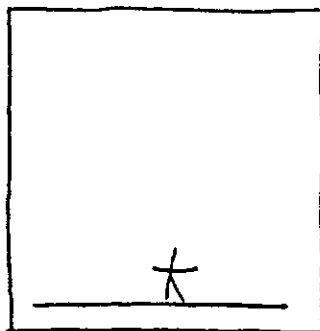
p. 127



BUILDING WITH GRASS

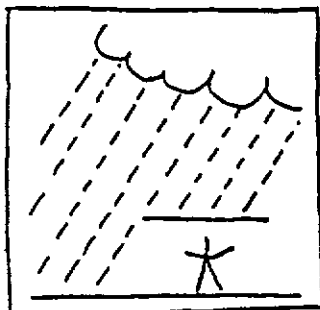
p. 133

CONTENTS

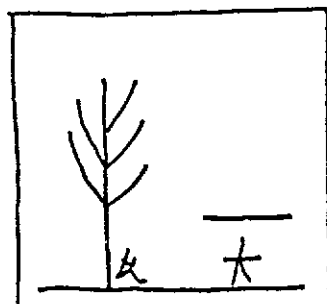


YOU DONT HAVE A HOUSE

IF YOU DONT HAVE A ROOF.

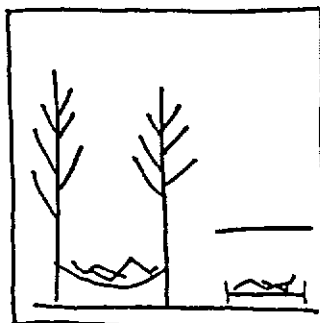


A HOUSE BEGINS WITH A ROOF,



BUT SOME PARTS OF THE HOUSE
DONT NEED TO HAVE A ROOF:

COURTYARDS,
TERRACES.



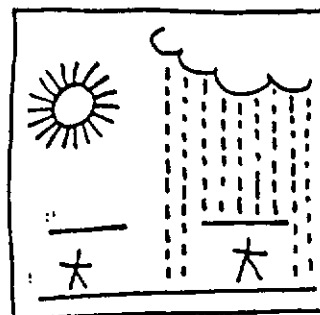
SOMETIMES
YOU PREFER TO BE AT HOME
UNDER A ROOF,

SOMETIMES YOU ARE AT HOME
HAVING ONLY THE SKY OVER YOUR HEAD.

WHAT YOU NEED TO BUILD
TO HAVE A HOUSE

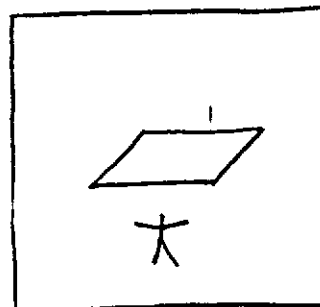
IS A ROOF.

A ROOF PROTECTS YOU
FROM THE SUN,
FROM THE RAIN:



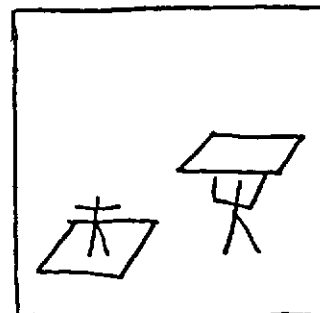
IT IS LIKE AN UMBRELLA.

A ROOF IS A SHEET

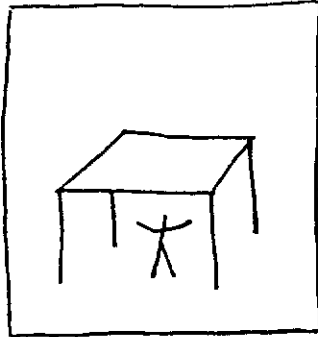


OVER YOUR HEAD;

THE SAME SHEET
IS NOT A ROOF

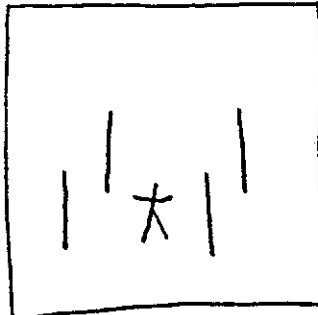


UNLESS YOU LIFT IT OVER YOUR HEAD

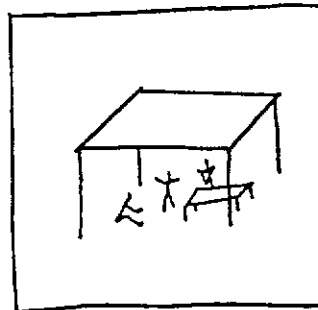


THE ROOF IS HELD
OVER YOUR HEAD

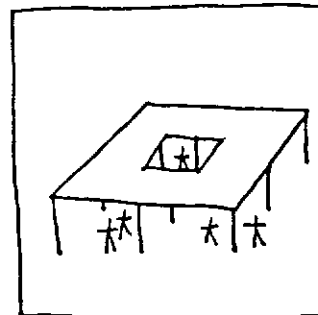
(FOR EXAMPLE)
BY A FEW STILTS.



THE STILTS ARE NOT A HOUSE.

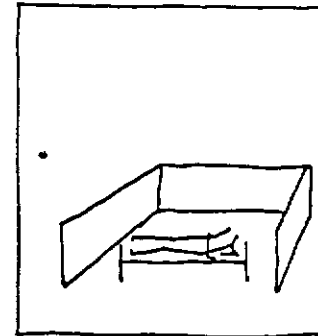


A ROOF ON STILTS
CAN BE A HOUSE.

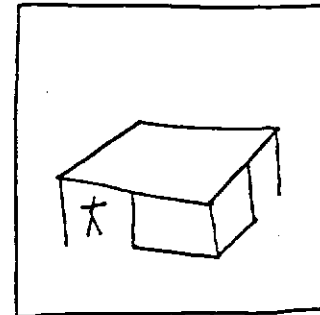


IF YOU OPEN A HOLE
IN THE ROOF ON THE STILTS,

YOU GET A COURTYARD.

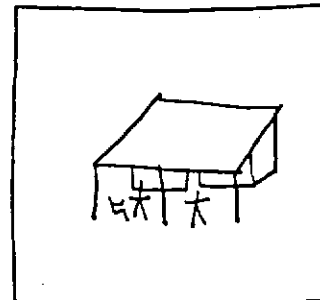


SOMETIMES YOU DONT WANT
PEOPLE TO SEE YOU
WHEN YOU ARE AT HOME.



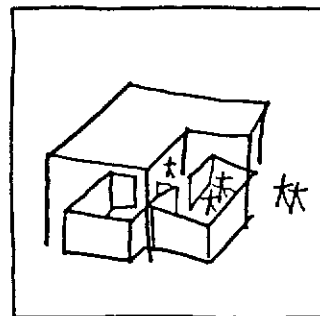
THEN YOU USE SCREENS,
TO HIDE THOSE PARTS OF YOUR HOME
YOU DONT WANT PEOPLE TO SEE

THESE SCREENS PROTECT ALSO
YOUR BELONGINGS FROM THEFT.



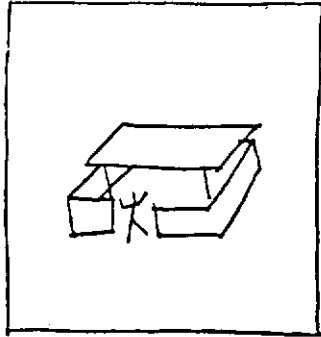
AT OTHER TIMES,
OR IN SOME OTHER PARTS OF YOUR HOME,
YOU LIKE TO BE SEEN
FROM OUTSIDE.

THERE YOU DONT USE SCREENS.



PARTS OF YOUR HOME
HIDDEN BY SCREENS
(HAVING OR NOT HAVING A ROOF)

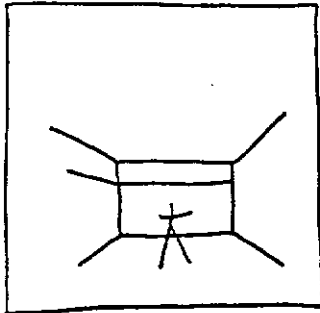
ARE ENCLOSURES.



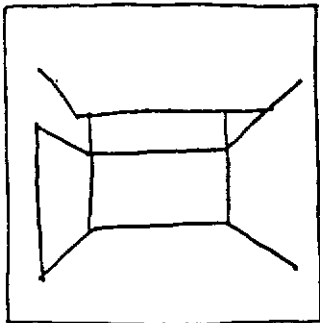
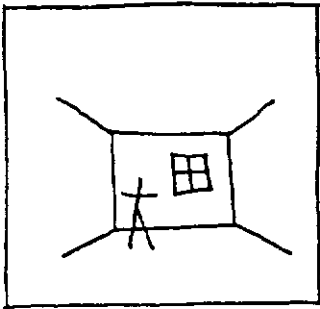
IF YOU HAVE ENCLOSURES

YOU HAVE TO LEAVE AN ENTRANCE,

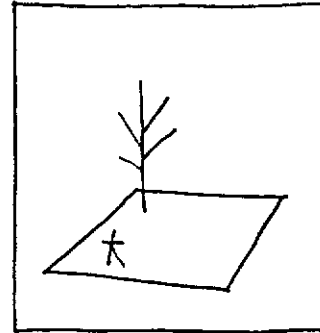
AND OPENINGS
FOR LIGHT AND AIR.



YOU CAN MAKE WINDOWS,



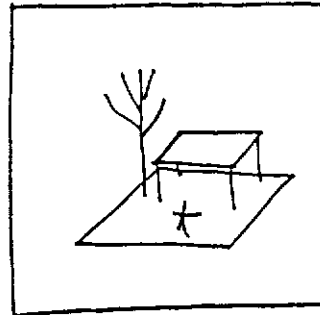
BUT IT IS SIMPLER AND CHEAPER
TO LEAVE A GAP
BETWEEN THE ROOF ON THE STILTS
AND THE UPPER EDGE OF THE SCREENS.



IF YOU NEED MATERIAL HELP
TO BUILD YOUR HOUSE

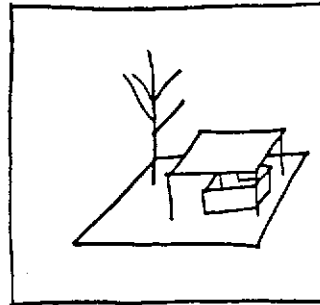
AND YOU HAVE GROUND TO BUILD ON,

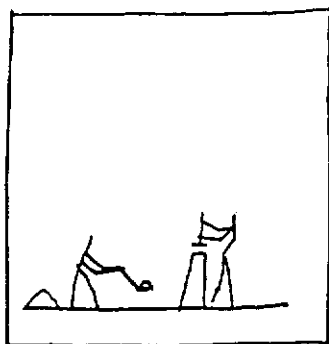
THE STILTS AND THE ROOF



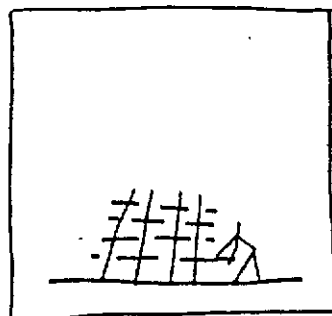
ARE THE MOST IMPORTANT,

THE SCREENS YOU CAN DO
YOURSELF.

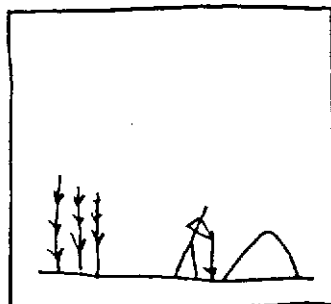




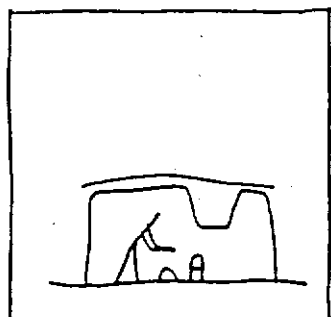
YOU CAN CONSTRUCT
THE WALLS
IN A WAY YOU ALREADY KNOW



IN MUD BRICKS OR MODELLED MUD WALLS
OR WITH WOVEN BRANCHES AND MATS.

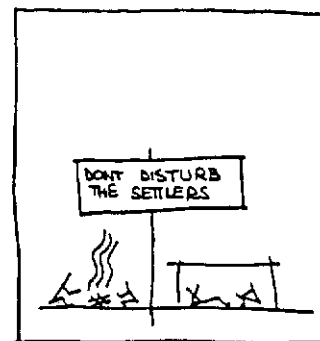


THESE TECHNIQUES ARE GOOD ONES
BECAUSE YOU YOURSELF
CAN FIND THE NECESSARY MATERIALS

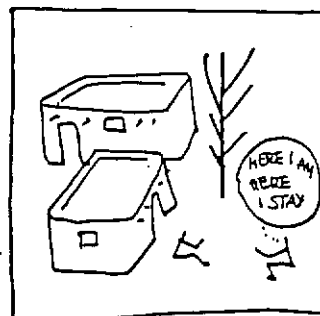


ON THE SPOT WHERE YOU LIVE,
AND YOU YOURSELF
KNOW HOW TO REPAIR SUCH WALLS

TO KEEP THEM IN A GOOD STATE
WITHOUT NEEDING OTHER PEOPLE'S HELP.

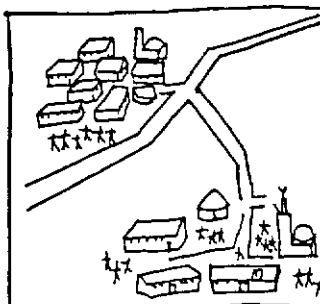


THE GOVERNMENT'S ROLE
IS, FIRST OF ALL,
TO PROTECT

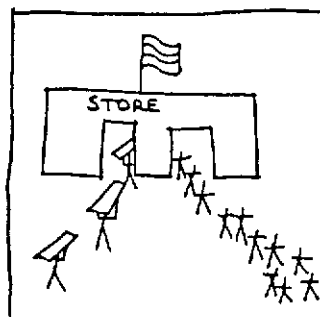


THE USER OF THE LAND:

THOSE WHO SQUAT SOMEWHERE
HAVE TO BE ASSURED



TO HAVE THE RIGHT TO STAY THERE.

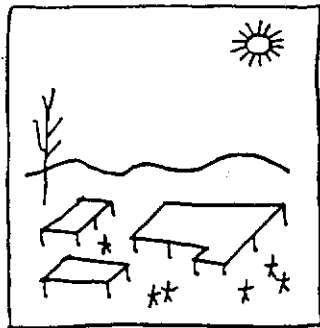


IT IS THE GOVERNMENT
WHO DECIDES ABOUT NETWORKS
(ROADS, WATER MAINS, SEWERS ETC)
WHICH ARE SUPPLIED THE COMMUNITIES

BUT THE INHABITANTS THEMSELVES
HAVE TO DECIDE
ABOUT NETWORKS
WITHIN THE COMMUNITY.

DISTRIBUTION
OF EXPENSIVE BUILDING MATERIALS
(FOR EXAMPLE, FOR THE ROOF)

IS THE GOVERNMENT'S TASK AS WELL.



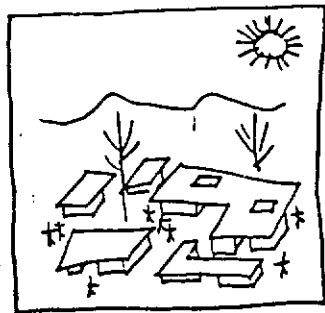
THE MOST IMPORTANT THING REQUIRED
FROM THE AUTHORITIES

IS THE RIGHT TO USE UNUSED LAND
AND MATERIAL FOR THE ROOF.

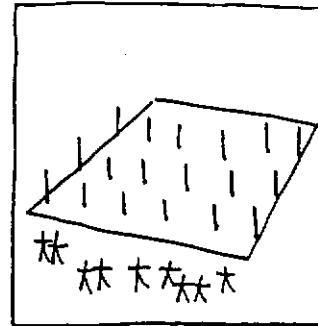
YOUR GOVERNMENT

CAN HELP YOU WITH BOTH.

IF YOU GET HELP
IN THESE TWO MATTERS



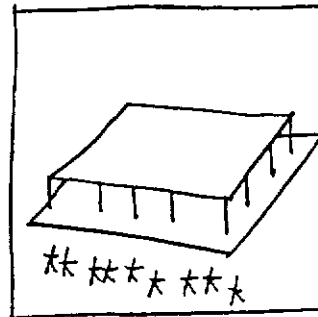
YOU WILL BE ABLE TO MAKE YOUR
OWN HOUSE.



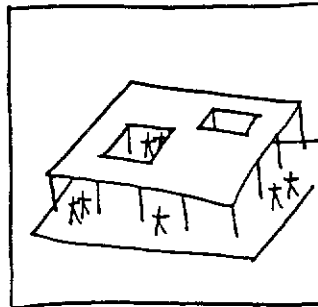
IF YOU OBTAIN SUCH LAND,
FOR YOU AND YOUR FRIENDS,

STILTS ON THE LAND,

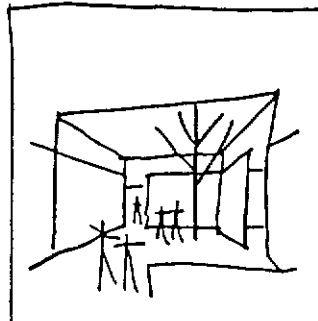
AND A ROOF IN COMMON
ON THE STILTS,

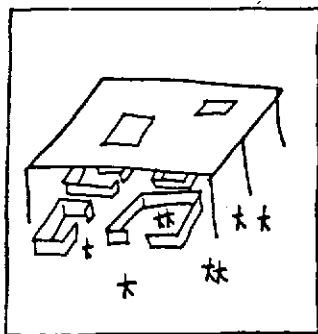


YOU CAN MAKE OPENINGS IN THE ROOF

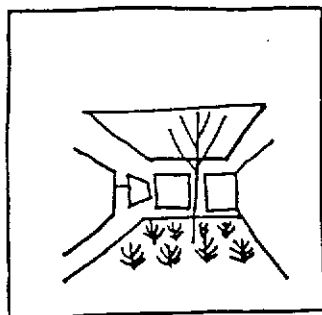


CREATING THUS COURTYARDS
GIVING LIGHT AND AIR AND
ACCESS TO ALL THE HOMES
SHARING THE SAME LAND AND ROOF.

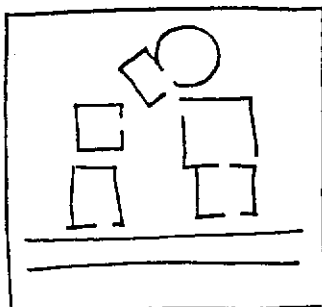




WHEN MAKING ENCLOSURES
UNDER THE "ROOF IN COMMON"



AND AROUND THE COURTYARDS,



EACH OF YOU
CAN PLAN THEM AS HE WANTS

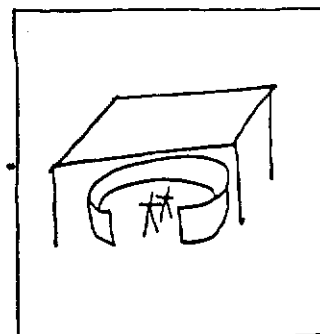
SOME ENCLOSURES CAN BE SQUARE,
SOME OTHERS ROUND,

SOME ENCLOSURES WIDE OPEN TO THE STREET,
SOME OTHERS DARK AND PRIVATE,

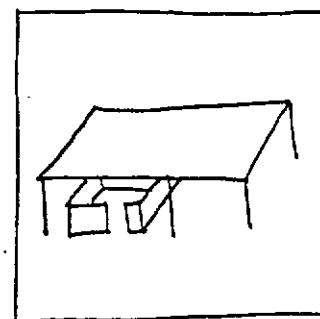
SOME ENCLOSURES LARGE,
SOME OTHERS SMALL

AND SO ON.

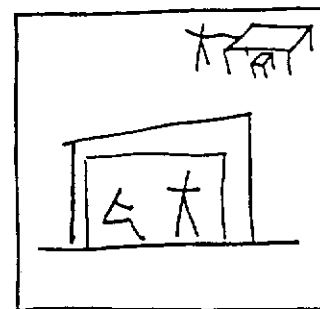
HOUSES ARE AS DIFFERENT AS PEOPLE.



YOU MIGHT LIKE SOME ENCLOSURES TO BE
ROUND,



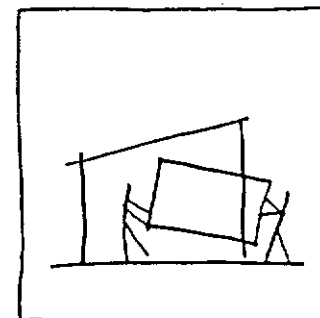
AND SOME OTHERS
SQUARE.



IF YOUR SCREENS (WALLS)
ARE SEPARATED
FROM THE STILTS SUPPORTING THE ROOF,

THEN
YOU CAN CHANGE THE SHAPE AND PLACE
OF YOUR SCREENS, AND MOVE THEM
(LIKE YOU CAN DO WITH A CHAIR
UNDER A TABLE)

WITHOUT THE ROOF FALLING IN.



BUT HOW TO MAKE THE PLAN OF YOUR HOUSE?

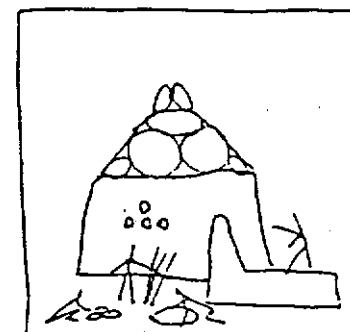


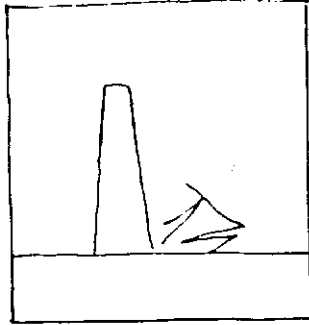
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



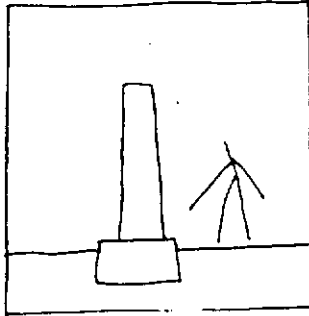
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

WHAT CAN YOU BUILD WITH
AND HOW?

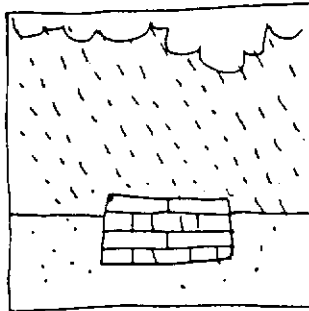




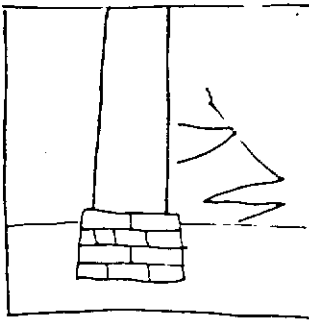
WALLS CAN START
DIRECTLY FROM THE GROUND.



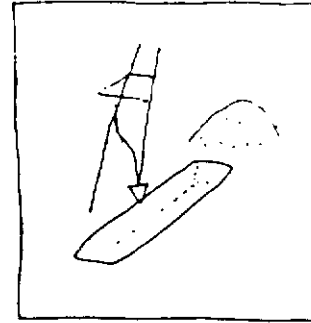
BUT IF YOU WANT TO HAVE THEM
MORE SOLID,



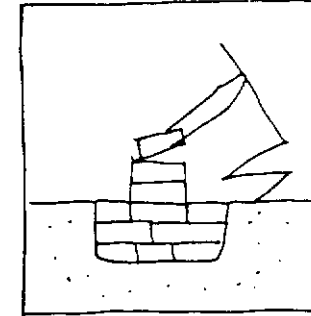
FOUNDATIONS ARE MADE
OF MATERIALS WHICH DO NOT BECOME SOFT
WHEN WET,



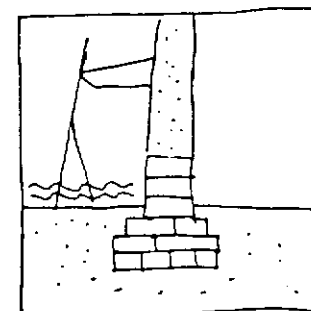
AND WHICH ARE SOLID ENOUGH
TO BEAR THE WEIGHT OF THE WALL.



FOR MAKING SOLID FOUNDATIONS
YOU FIRST DIG A DITCH
DEEP ENOUGH TO REACH
THOSE LAYERS OF THE SOIL WHICH DON'T MOVE

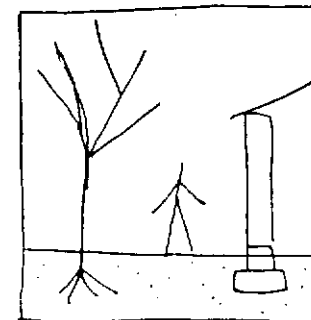


AND BROAD ENOUGH TO DISTRIBUTE
THE WEIGHT OF THE WALL FOR THE SOIL.



YOU PUT BRICKS OR STONES
INTO THIS DITCH
IF YOUR HOUSE WILL HAVE HEAVY WALLS,

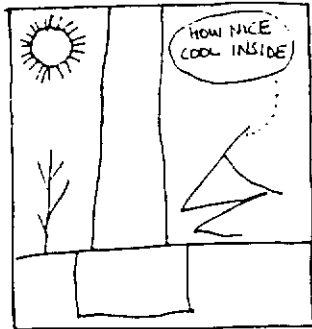
AND YOU SHOULD MAKE
THE LOWEST LAYERS OF THE WALL
OF THE SAME MATERIALS.



SO EVEN HIGH WATER
DOES NOT DO MUCH HARM
TO YOUR WALLS.

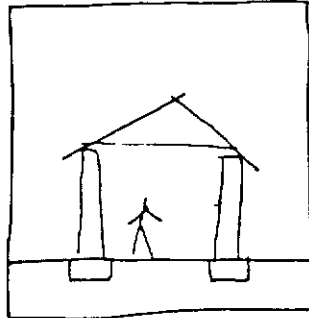
FOUNDATIONS ARE THE ROOTS OF THE HOUSE,

AND LIKE ROOTS DO,
THEY ARE DEEPER AND LARGER
THEN ARE THE WALLS THEMSELVES.

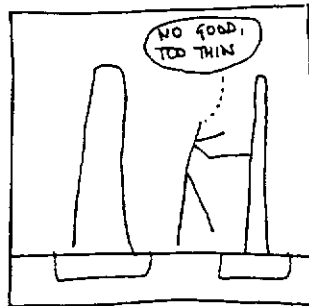


WALLS
KEEP HEAT, COLD AND WATER
OUT OF THE HOUSE

AND CAN BE USEFUL
TO HIDE THINGS
YOU WANT TO KEEP HIDDEN.



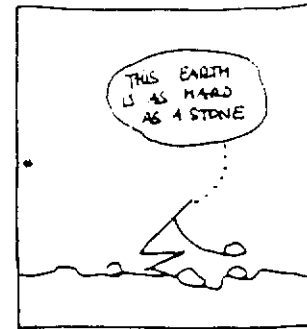
WALLS CAN ALSO BEAR THE ROOF.



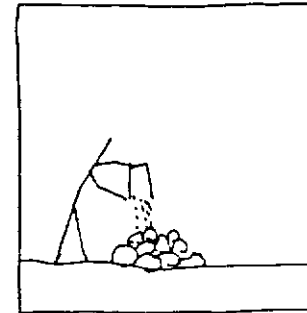
WALLS WHICH BEAR THE ROOF
MUST BE SOLID
AND OFTEN HEAVY:

MADE OUT OF DRY EARTH,
OR SUN-DRIED EARTHEN BRICKS,
OR BRICKS BURNT IN FIRE
OR STONES,

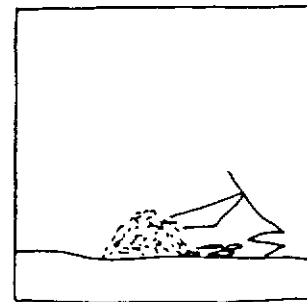
WHICHEVER ARE ACCESSIBLE FOR YOU.



IN ORDER TO BUILD WITH MUD
YOU HAVE TO HAVE EARTH
WHICH GETS HARD WHEN DRY.

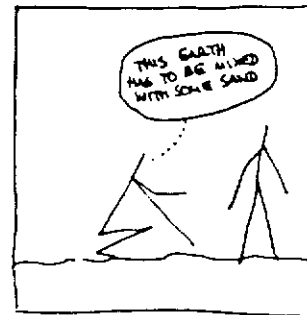


WHEN YOU USE SUCH EARTH WHICH SHOULD
BE WET ENOUGH TO BE MUD, BUT
NOT TOO LIQUID,



YOU HAVE TO MIX IT WITH
CHOPPED STRAW,
COW DUNG,
SMALL PEBBLESTONES OR GRAVEL,

ALL MATERIALS WHICH MAKE DRY MUD
MORE SOLID.

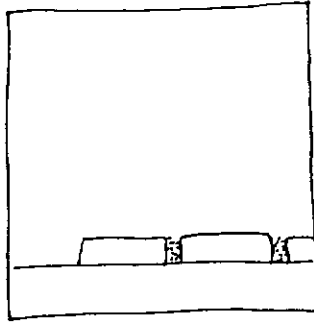


OCCASIONALLY YOU CAN MIX THIS MUD
WITH SOME SAND

MOST PEOPLE LIVING IN A PLACE
KNOW HOW GOOD THEIR EARTH IS FOR BUILDING.

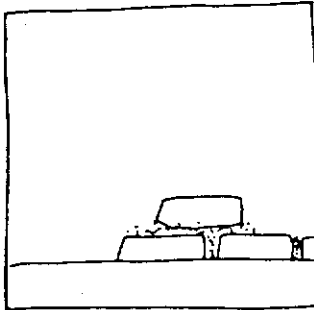
WHEN BUILDING WITH BRICKS
(EARTHEN ONES, SUNDRIED OR BURNT)

YOU HAVE TO BE VERY CAREFUL
WHEN BUILDING A BRICK WALL

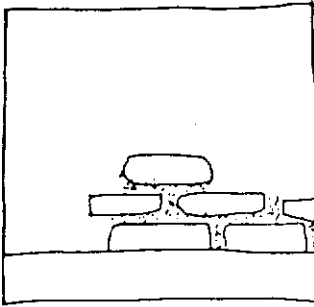


YOU LAY A ROW OF BRICKS
PUTTING SOME WET MUD (MORTAR)
BETWEEN ANY TWO BRICKS.

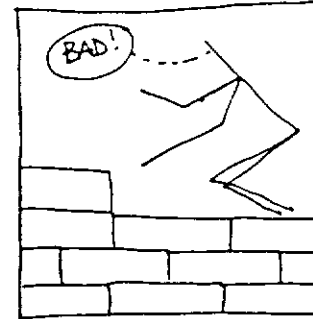
SO YOU PUT A BRICK, MORTAR,
ANOTHER BRICK MORE MORTAR,
AND SO ON.



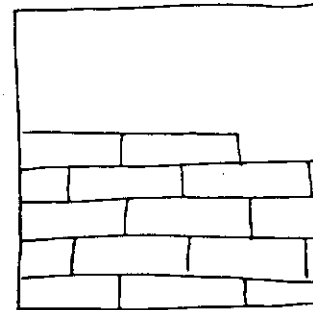
WHEN THE FIRST ROW OF BRICKS
IS LAYED OUT,
YOU SHOULD PUT MORTAR ON THE TOP
OF EACH BRICK,



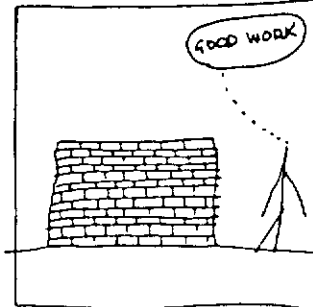
BEFORE PLACING
A BRICK OF THE NEXT LAYER
ON IT.



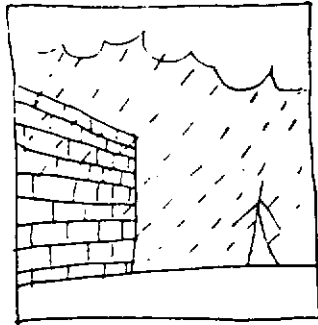
AND WATCH THAT THERE IS NEVER
A JOIN BETWEEN TWO BRICKS
OF ONE ROW
DIRECTLY ABOVE A JOINT OF THE ROW
BENEATH.



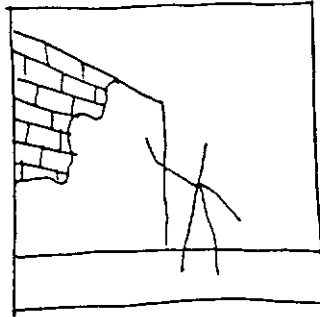
JOINTS OF A ROW
SHOULD BE SHIFTED
IN RELATION TO THE JOINTS
OF ROWS ABOVE AND BELOW IT.



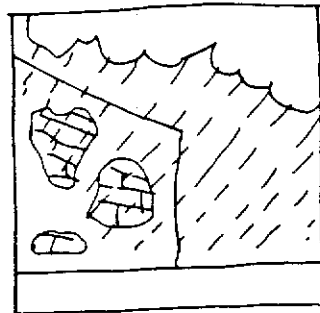
IF YOU DO IT WELL
YOUR WALL WILL BE MORE SOLID.



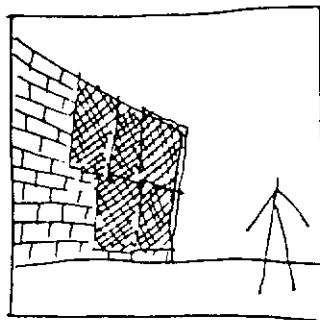
ONCE THE WALL IS BUILT,
IT HAS TO BE PROTECTED
AGAINST HUMIDITY.



YOU CAN DO THIS WITH PLASTER,
APPLIED TO BOTH THE EXTERIOR
AND INTERIOR SURFACE OF THE WALL.

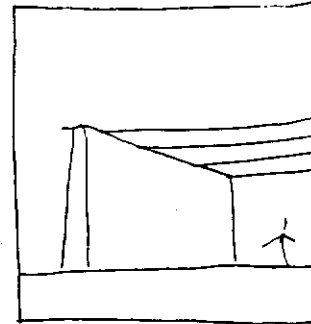


BUT PLASTER IS OFTEN
NOT PROTECTIVE ENOUGH
FOR MUD WALLS.

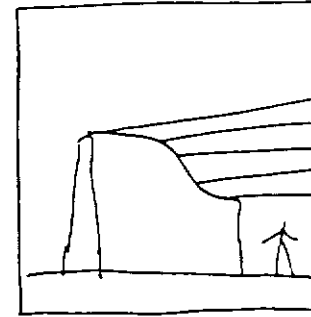


BETTER PROTECTION CAN BE ASSURED
BY FASTENING A STRAW MAT
ON THE OUTER SURFACE OF THE WALL.

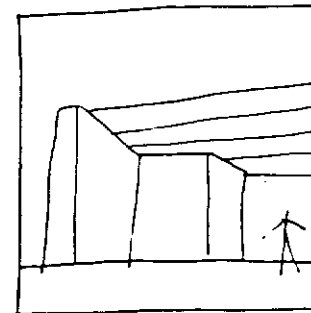
THE MAT LETS MOST OF THE WATER TRICKLE DOWN
AND IT SHIELDS THE MUD WALL FROM THE RAIN BEAT



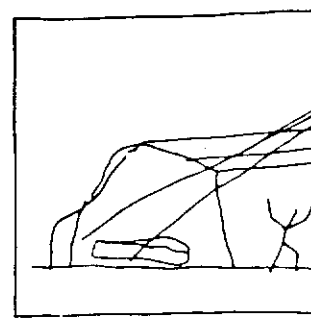
YOU WILL FIND
THAT A WALL
WHICH IS BUILT IN A STRAIGHT LINE



IS LESS SOLID THAN A CURVED WALL

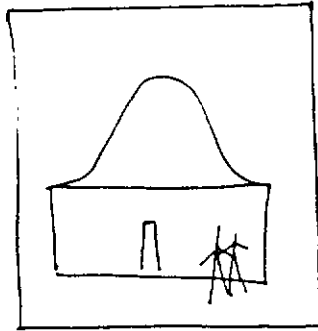


OR ONE BUILT ON A BROKEN LINE:

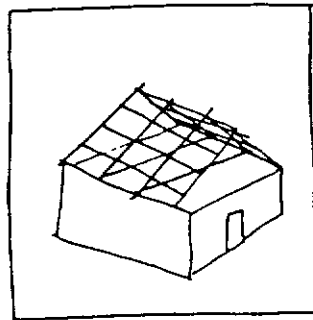


A STRAIGHT WALL STANDING ALONE
CAN NOT LEAN ON ITSELF,
WHICH A CURVED WALL CAN DO.

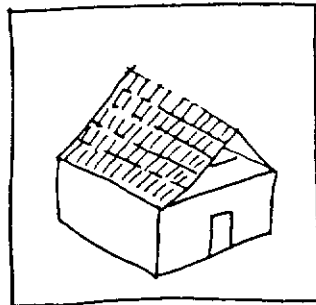
THUS A STRAIGHT WALL COLLAPSES MORE EASILY.



ROOFS CAN BE BUILT IN MANY WAYS

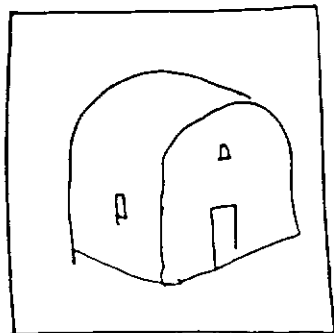


BUT THEY HAVE ALWAYS ONE THING
IN COMMON:

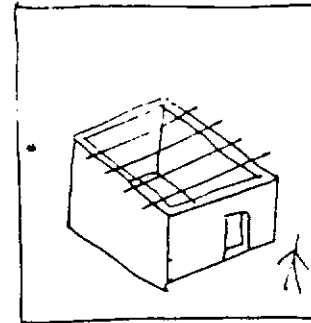


THERE IS A "STRUCTURE"
WHICH BEARS A WATER-TIGHT LAYER,

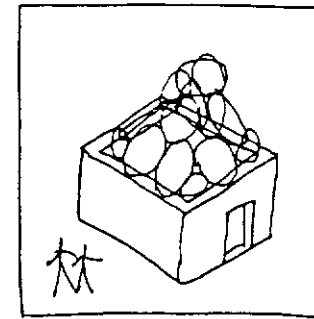
AND THERE IS THE WATER-TIGHT LAYER
ITSELF.



IN MANY CASES THE TWO
CAN BE THE SAME.



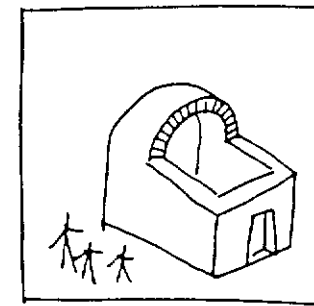
THE BEARING "STRUCTURE"
CAN BE:



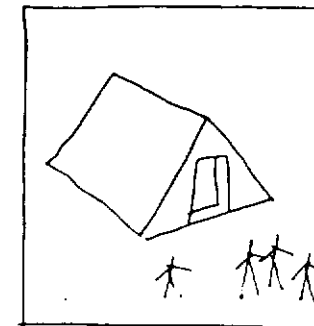
SIMPLE TIMBER GIRDEES,

DOME OR VAULT "STRUCTURE"
IN LIGHT MATERIALS, LIKE

BAMBOO,
GRASS BUNDLES,
ETC.



IT CAN BE BUILT IN MASONRY ARCHES
AS WELL,



SOMETIMES THE FORM OF THE HOUSE
CAN BE SO
THAT WALLS AND ROOFS ARE THE SAME.



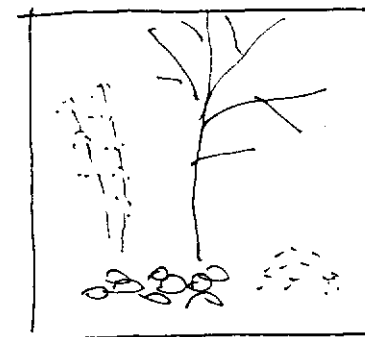
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

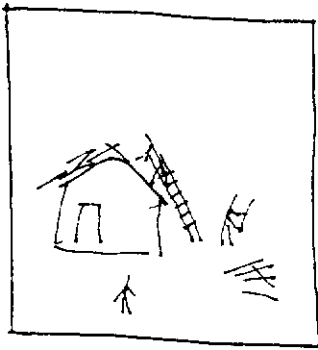


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BO GARIBOLDI, 75015 PARIS ☎ (331) 783-20-24

CHOOSING MATERIALS

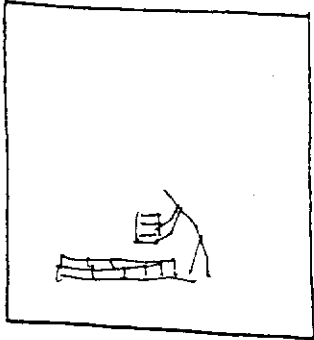




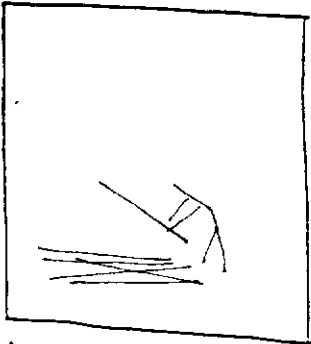
THERE ARE MANY MATERIALS
WITH WHICH ONE CAN BUILD

HIS HOUSE,

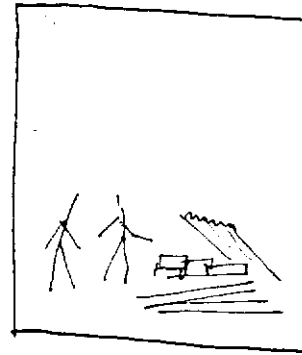
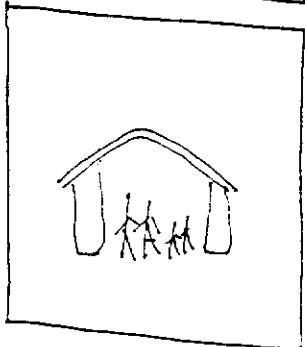
WALLS



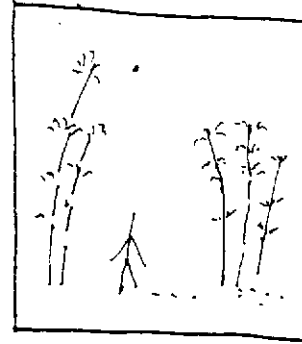
AND ROOF



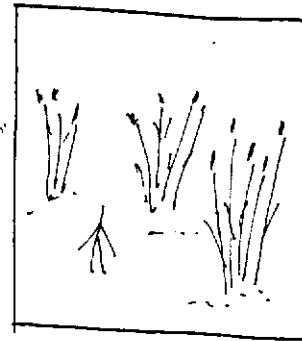
FOR HIS FAMILY.



SOME OF THESE MATERIALS
ARE LESS EXPENSIVE
THAN OTHERS:

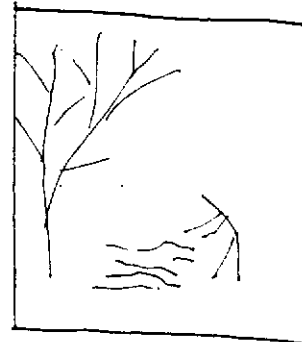


THOSE WHICH CAN BE GROWN
ANYWHERE
(LIKE BAMBOO)

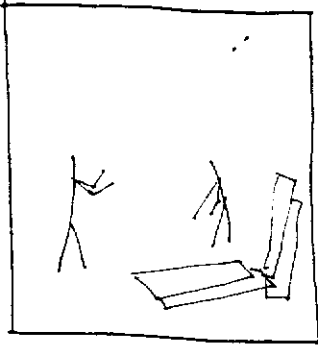


OR WHICH NATURALLY GROW
IN ABUNDANCE
IN CERTAIN REGIONS

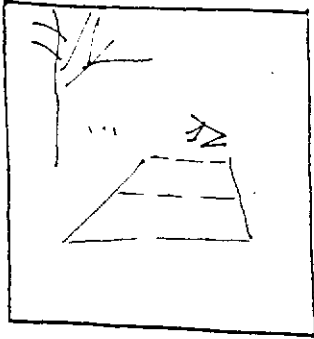
(LIKE REEDS



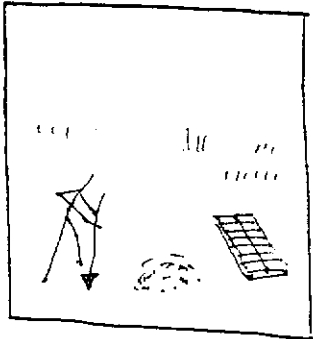
OR TREES
WITH STRONG BRANCHES).



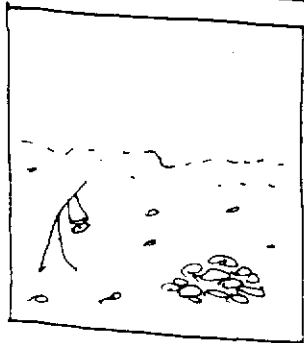
OTHER MATERIALS
WHICH ARE INEXPENSIVE



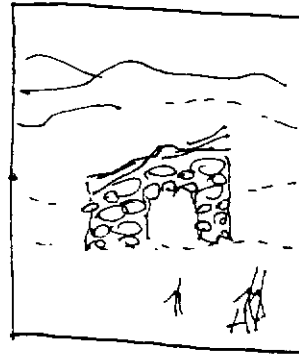
CAN BE FOUND IN ABUNDANCE
NEAR THE PLACE
WHERE THE HOUSE WILL BE BUILT:



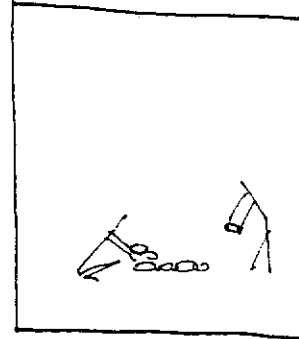
SUCH ARE: MUD
FOR SUNDRIED BRICKS



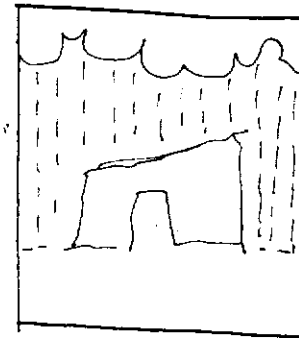
OR, IN SOME REGIONS, STONE.



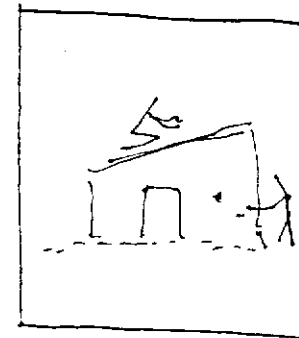
BUILDING WITH SUCH MATERIALS
MAKE THE HOUSE INEXPENSIVE



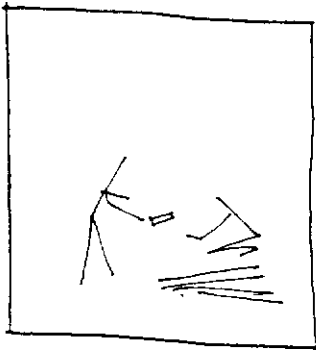
IF ONE CAN DO THE BUILDING JOB
HIMSELF.



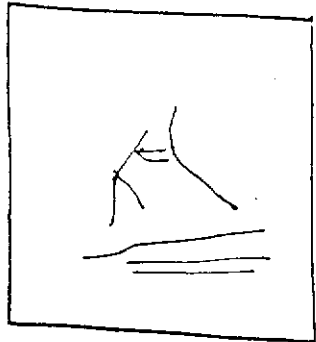
THAT KIND OF HOUSE
CAN STAND FOR A LONG TIME



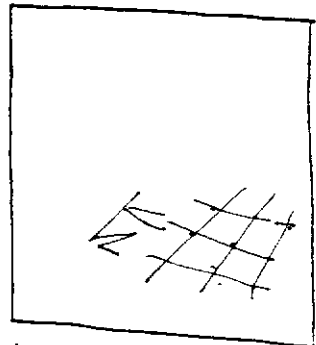
IF IT IS CAREFULLY MENDED
EVERY YEAR.



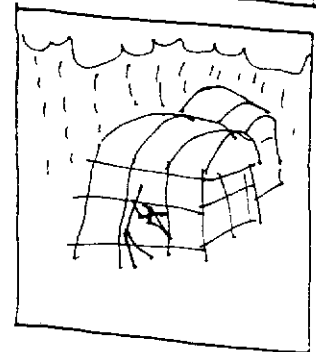
CHOOSING MATERIALS TO BUILD
IS NOT ONLY A QUESTION OF COST.



IT IS IMPORTANT TO EXAMINE
HOW LONG THAT MATERIAL
WILL LAST,

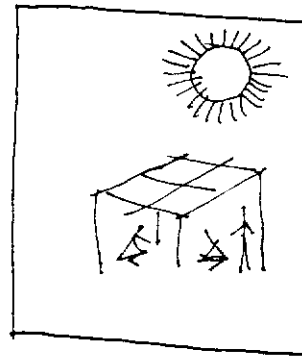


HOW EASY IS IT
TO BUILD WITH IT ?

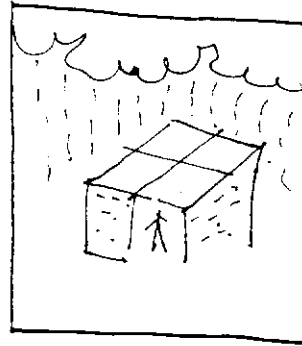


AND HOW APPROPRIATE IT CAN BE
TO PROTECT YOU
AGAINST WEATHER,

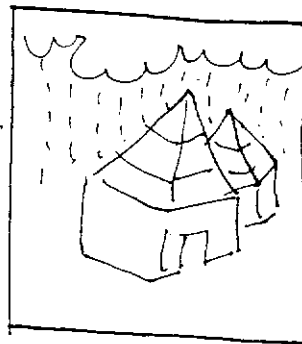
AGAINST ANIMALS
AND AGAINST ILLWILLED PEOPLE.



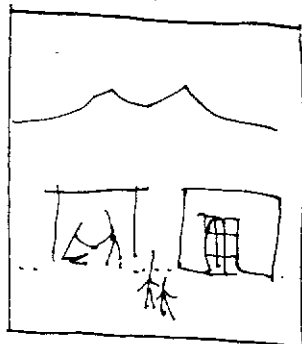
BUT, PROTECTION
AGAINST CLIMATE



IS NOT DEPENDENT
UPON THE MATERIAL ALONE:



THE WAY IT IS USED
MIGHT BE EVEN MORE DECISIVE.

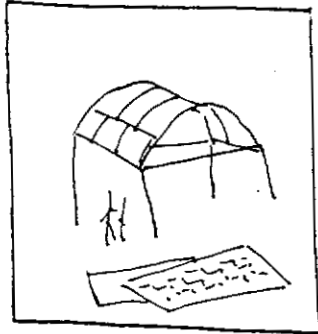


IT IS IMPORTANT TO KNOW ALSO
WHAT TO EXPECT
FROM THAT BUILDING.

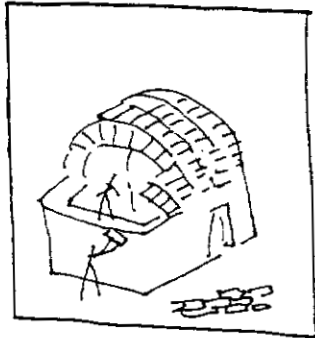


VEGETAL MATERIALS, FOR EXAMPLE,
(BAMBOO, REEDS OR BRANCHES)

ARE VERY GOOD ROOF SUPPORTS,
AND, IN MANY CASES,
CAN BE USED AS ROOF COVER

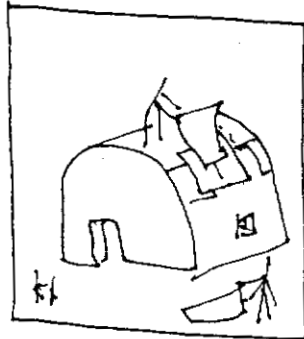


(MADE OF MATS, STRAW
OR LEAFS).



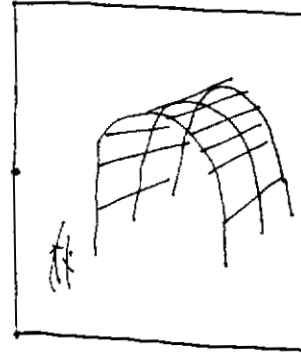
VAULTS AND DOMES
BUILT WITH STONES
OR KILNBURNT BRICKS

ARE BOTH GOOD AS SUPPORT
AND AS ROOF COVER.

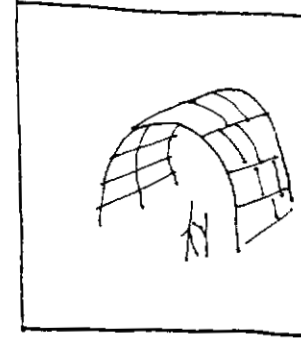


IT IS A DIFFERENT CASE
WITH MUD BRICKS,
VAULTS OR DOMES

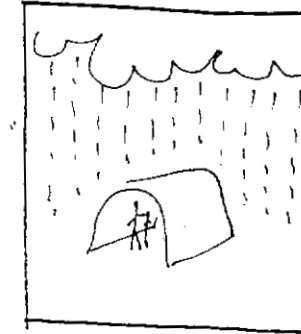
WHICH NEED TO BE PROTECTED
FROM MOISTURE,
OTHERWISE THEY COLLAPSE.



IT IS IMPORTANT TO KNOW
HOW TO CHOOSE
MATERIALS AND TECHNIQUE



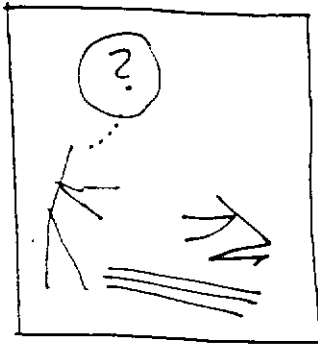
FOR THE SUPPORTING STRUCTURE
AND FOR THE ROOF COVER,



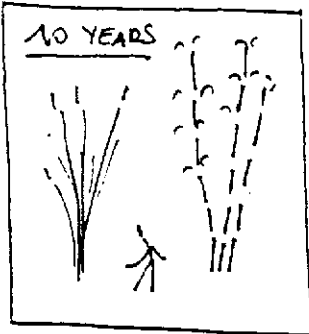
APPROPRIATE TO CLIMATES



AND TO THE ABUNDANCE
OF INEXPENSIVE MATERIALS.

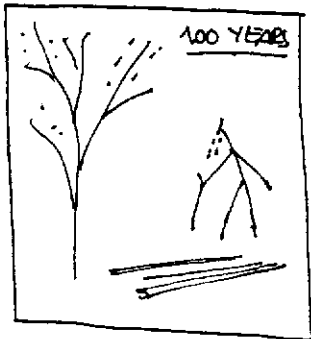


AN IMPORTANT POINT OF VIEW
WITH BUILDING MATERIALS
CONCERNS THEIR LIFETIME.

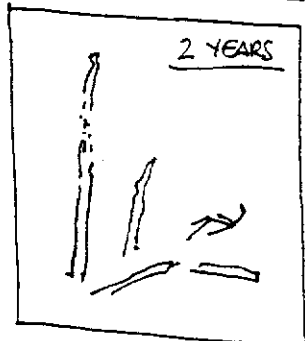


MOST MATERIALS
KEEP ONLY FOR A LIMITED TIME:

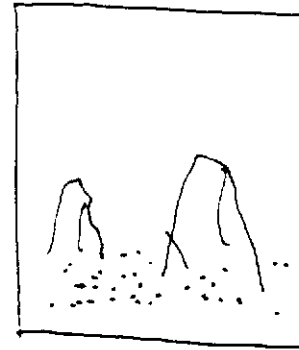
REEDS AND BAMBOO DECAY
IN ABOUT 10 YEARS,
SOMEWHAT LONGER UNDER CERTAIN CLIMATES.



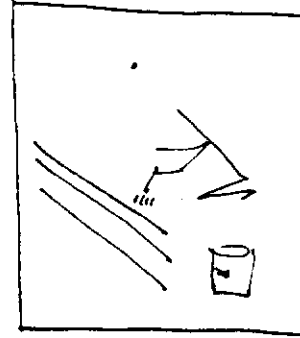
WOOD CAN KEEP EVEN UP TO 100 YEARS
(IT DEPENDS ON WHAT KIND OF WOOD).



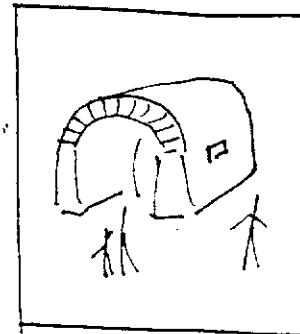
CASUARINA WOOD, FOR EXAMPLE
KEEPS FOR A SHORTER TIME
THAN BAMBOO.



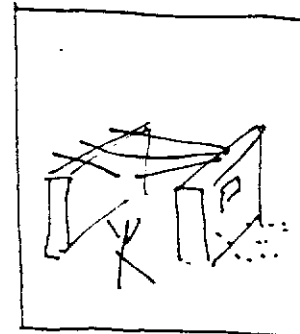
VEGETAL MATERIALS
ARE SUBJECT TO PESTS,
PARTICULARLY TO TERMITES.



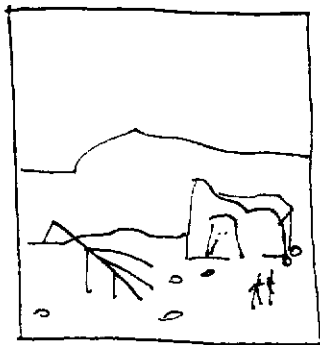
IT IS DIFFICULT AND EXPENSIVE
TO PROTECT THOSE MATERIALS
AGAINST TERMITES.



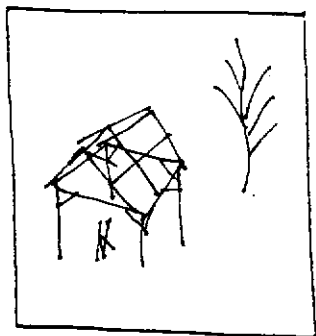
IN TERMITE-SMITTEN REGIONS
TO BUILD WITH BRICKS
OR STONES



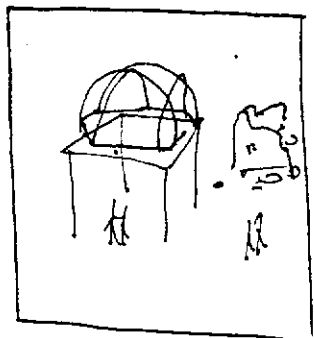
MIGHT BE MORE REASONABLE
THAN TO BUILD WITH MATERIALS
OF VEGETAL ORIGIN.



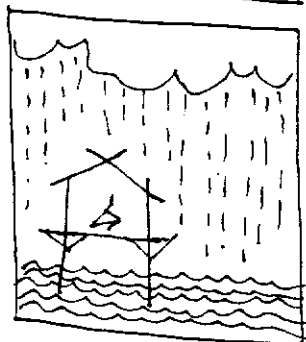
IN REGIONS
WHERE EARTHQUAKES ARE FREQUENT,



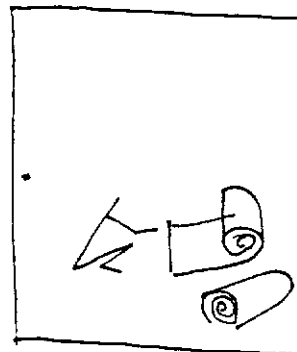
VEGETAL MATERIALS, FOR STRUCTURE,
GRANT MORE SECURITY



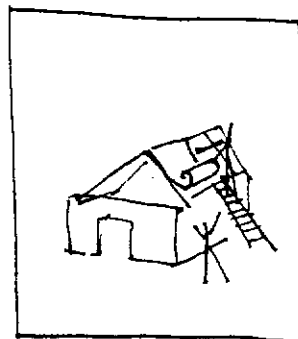
PROVIDED, THEY ARE USED
IN THE PROPER WAY.



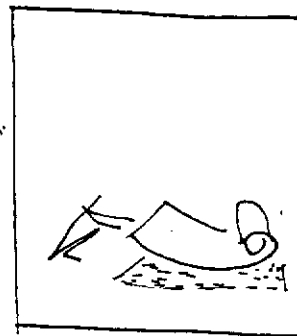
SUCH MATERIALS CAN BE ADVANTAGEOUS
IN PLACES
WHERE TIDES ARE COMMON.



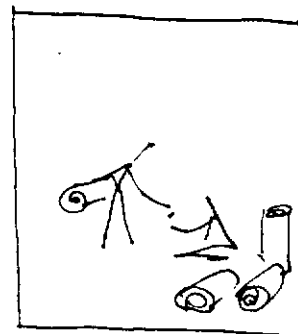
BESIDE USING LOCAL MATERIALS,
MATERIALS OF INDUSTRIAL ORIGIN
CAN BE THE BETTER
FOR CERTAIN TASKS:



SUCH, AS MAKING THE ROOF
WATER-PROOF



WITH PLASTIC FOLLS,
OR, BOTH WATERPROOF
AND PROTECTED HEAT



WITH ALUMINIUM FOLLS.
BOTH MATERIALS
ARE NOT VERY EXPENSIVE

WHEN THEIR EFFICIENCY
IS TAKEN IN ACCOUNT.



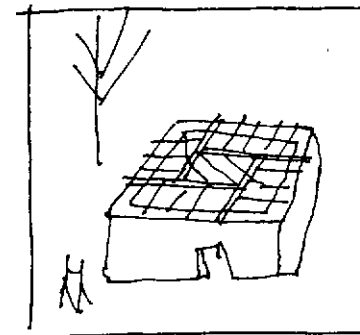
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

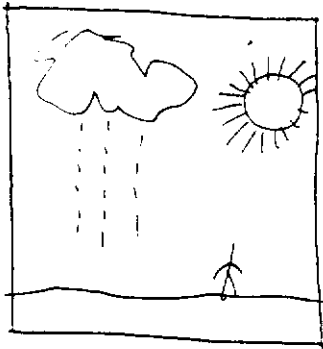


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

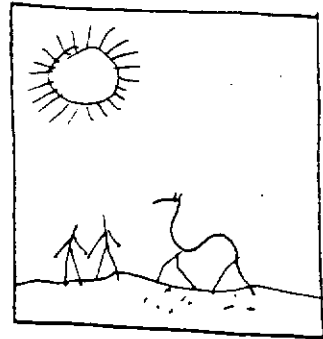
33, BD GARIBOLDI, 75015 PARIS ☎ (331) 783-20-24

FLAT ROOFS

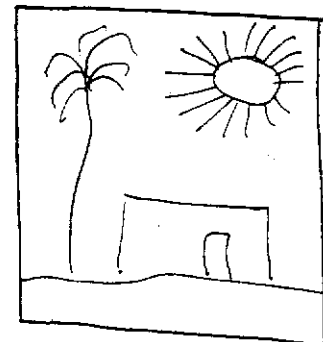




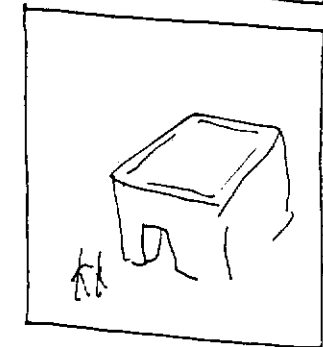
IN PLACES
WHERE THERE IS LITTLE RAIN,



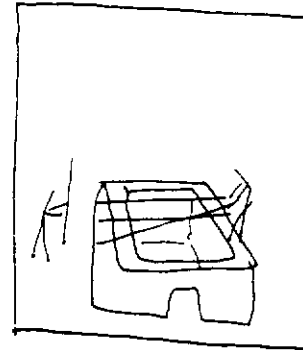
AND WHERE RAIN IS NOT FREQUENT,



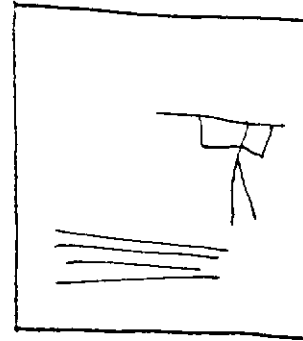
WATERTIGHT ROOFS
IS NOT THE MAIN PRIORITY



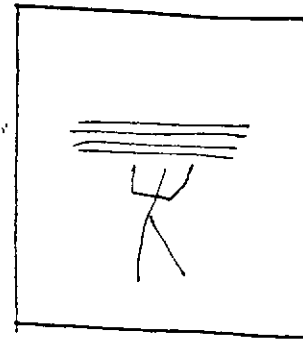
IN SUCH PLACES
FLAT ROOFS CAN BE APPROPRIATE.



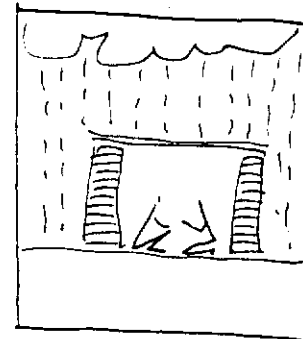
FLAT ROOFS
ARE EASY TO BUILD.



THEY USE UP
ONLY LITTLE MATERIAL

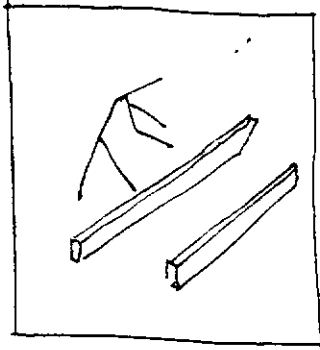


(PARTICULARLY IF THOSE MATERIALS
USED FOR THE ROOF
ARE LIGHT)

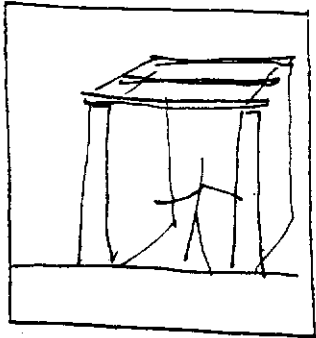


BUT
EVEN IF THEY
ARE BUILT IN SEMI-ARID REGIONS,

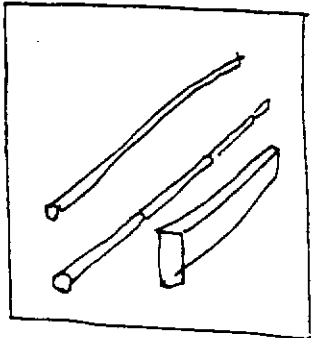
THEY SHOULD BE
RESISTANT TO WATER



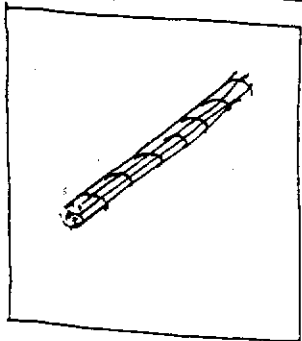
THE ESSENTIAL PART OF FLAT ROOFS
IS THE BEAMS.



BEAMS CAN BE MADE
OF VARIOUS MATERIALS:

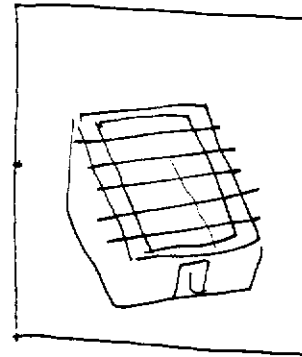


WOOD,
BAMBOO,
METAL RODS,

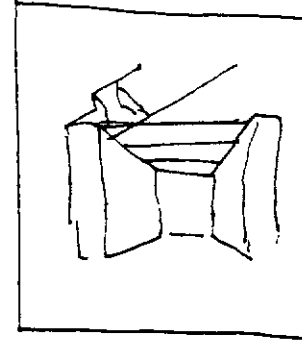


EVEN BUNDLES OF REED
CAN BE USED

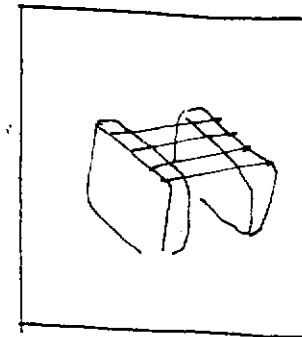
FOR BEAMS.



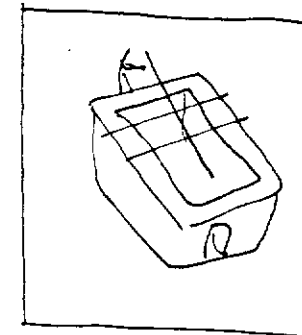
THE SIMPLEST ARRANGEMENT
OF BEAMS



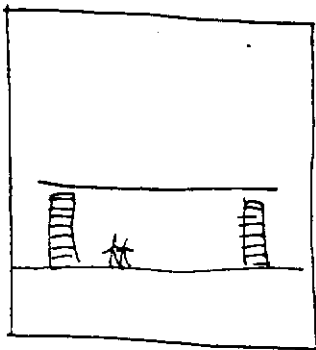
CONSISTS IN SPANNING
THE DISTANCE



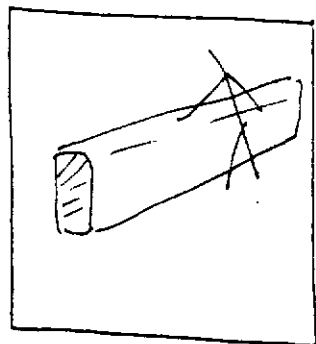
BETWEEN TWO OPPOSITE WALLS.



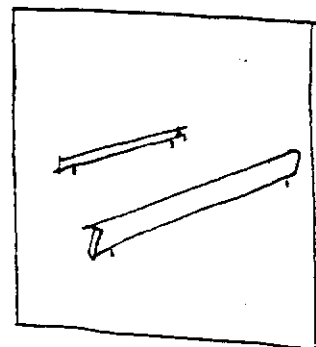
OBVIOUSLY, IF YOU HAVE THE CHOICE
YOU TAKE THE SMALLER SPAN.



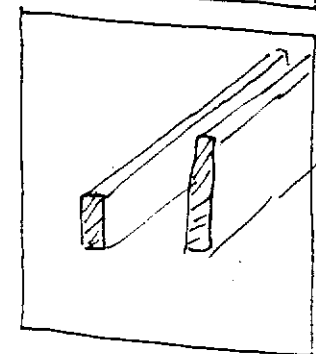
USING BEAMS IN THIS WAY
THEY SOMETIMES HAVE TO BE LONG
(AS THE WALLS CAN BE FAR APART).



THEN THEY HAVE TO BE
STRONG AS WELL,

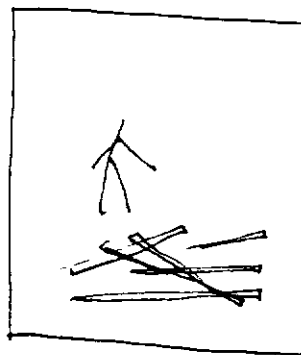


THUS QUITE THICK AND HIGH,
AND SO RATHER EXPENSIVE.

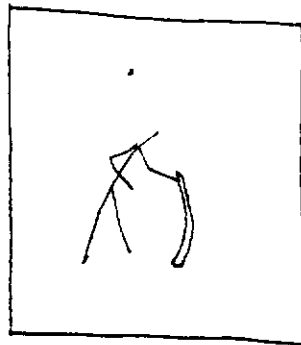


NOTE: IF THE SPAN DOUBLES,
FOR EXAMPLE,

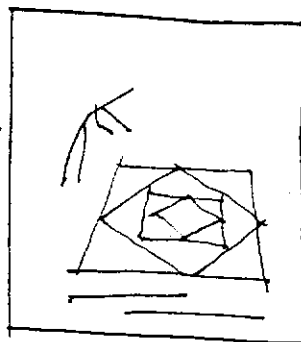
THE BEAM NEEDS TO BE
TWICE AS HIGH.



IF THE PIECES OF WOOD, OR BAMBOO
ARE NOT LONG ENOUGH,



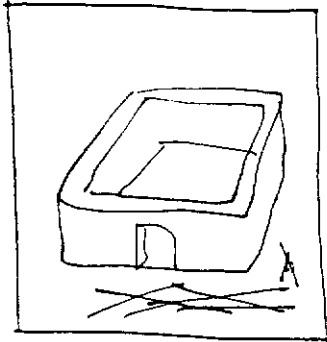
OR STRONG ENOUGH,



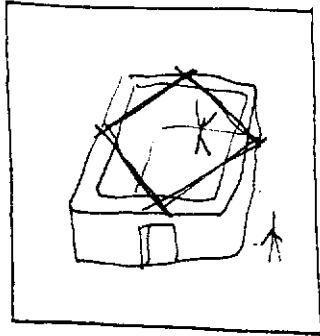
YOU CAN MAKE
OTHER PATTERNS OF BEAMS



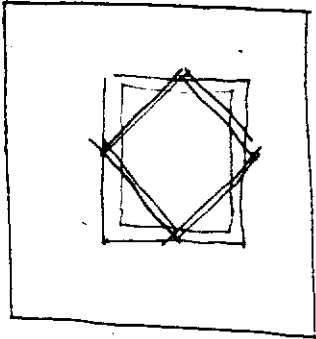
WHICH MIGHT BE LESS EXPENSIVE.



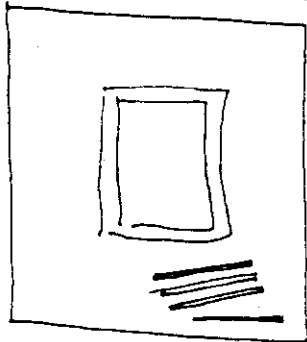
YOU CAN, FOR EXAMPLE,
POSE THOSE SHORTER PIECES



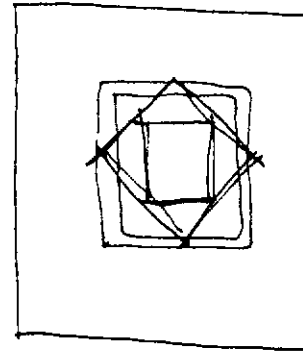
IN DIAGONALS
CUTTING OFF THE CORNERS.



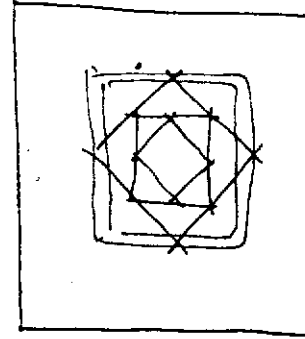
THUS 4 PIECES OF WOOD
WILL FORM A SMALLER SQUARE
THAN WAS THE ORIGINAL ROOM.



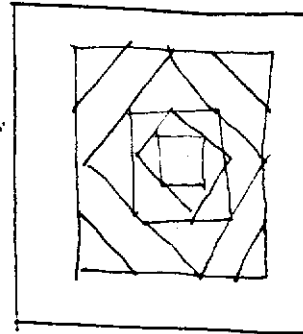
YOU START THUS
TO REDUCE THE SPAN.



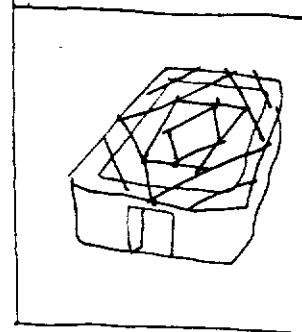
THEN YOU CONTINUE
WITH THE SAME METHOD



(BY CUTTING OFF CORNERS)
MAKING THAT SMALLER SQUARE
EVEN SMALLER

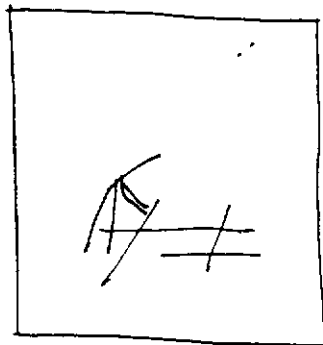


YOU CAN CONTINUE THUS
FROM SMALL SQUARE



TO SMALLER SQUARE.

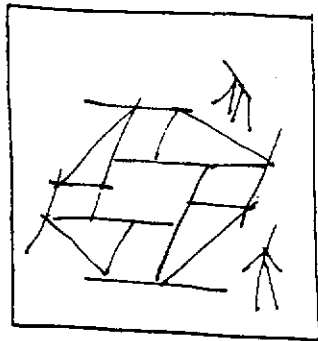
AS A RESULT
YOU GET A GRID OF BEAMS,
WITH SMALLER PIECES OF WOOD.



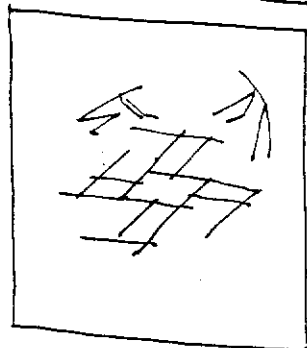
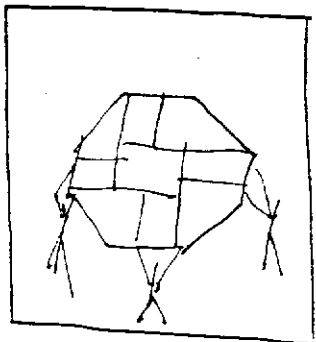
ANOTHER SOLUTION
TO THE SAME PROBLEM

CONSISTS OF MAKING A BEAM-NET
ON THE GROUND.

ONCE THE NET IS FINISHED ,
ON THE GROUND

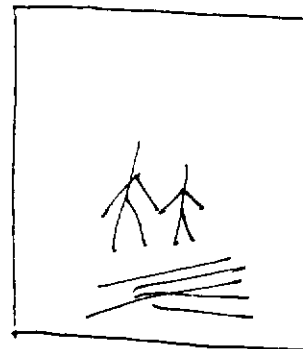


YOU HAVE TO LIFT IT
INTO ITS PLACE
AND FASTEN IT ONTO THE WALLS.

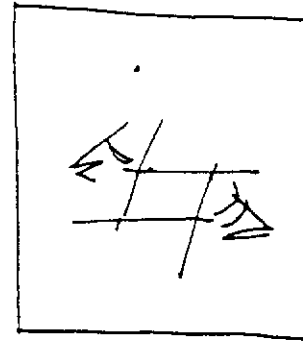


SUCH A NET IS TOO COMPLICATED
TO BE BUILT DIRECTLY
IN ITS FINAL PLACE.

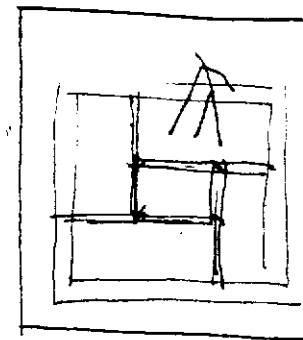
BESIDE THAT,
YOU CAN DRAW THE PATTERN
ON THE GROUND, WHICH SIMPLIFIES THINGS.



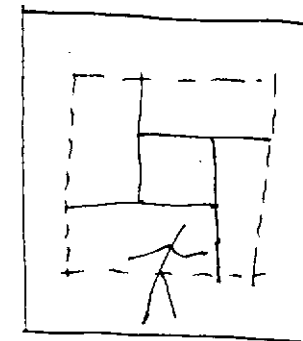
TO MAKE THIS BEAM-NET



YOU SHOULD START
BY TYING TOGETHER
A PIECES OF WOOD
(USING FOR THIS
A VERY SOLID ROPE).

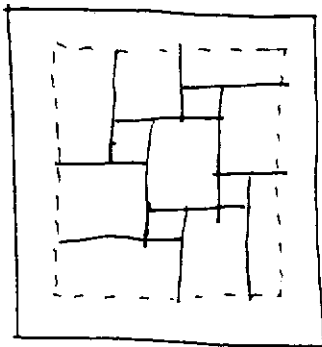


SO THAT THEY SHOULD FORM
A SMALL SQUARE IN THE
CENTER

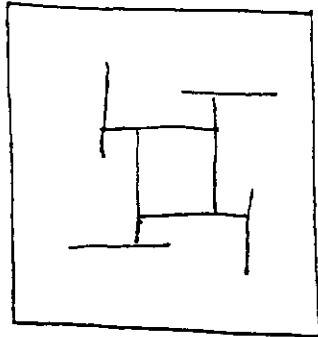


AND THAT EACH PIECE OF WOOD
SHOULD STICK OUT
OF THE SQUARE

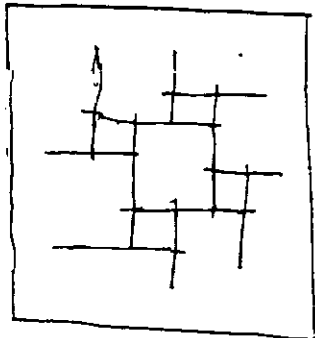
ONLY ON ONE SIDE.



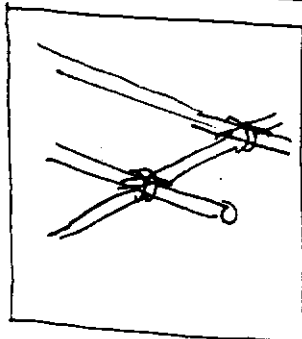
THAT "SQUARE WITH STEMS"
WILL BE THE CENTER
OF THE NET.



TIE NOW 4 OTHER PIECES OF WOOD
TO EACH STEM,
PERPENDICULAR TO THE STEM,

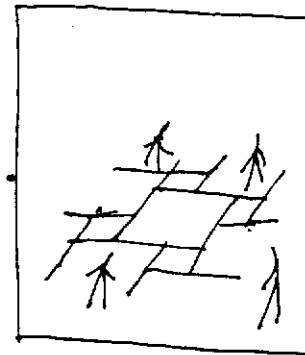


AND AGAIN 4 OTHER PIECES
TO THE MIDDLE
OF EACH SIDE OF THE SQUARE,
PERPENDICULAR TO THAT SIDE.

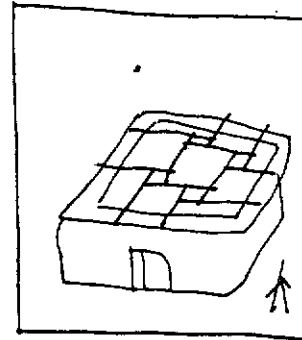


ONCE THIS MADE,
TIE TOGETHER THOSE PIECES,
LIKE THE DRAWING SHOWS.

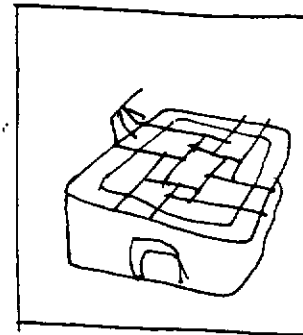
YOU SHOULD TIE WELL
AND WITH A SOLID ROPE.



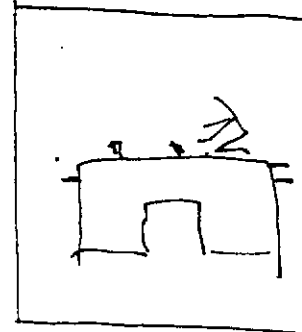
ONCE YOU HAVE FINISHED
TYING THE NET TOGETHER



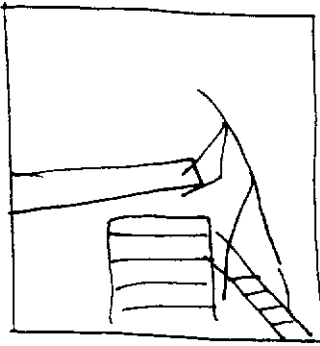
YOU CAN LIFT IT
INTO ITS FINAL PLACE



AND FIX IT WELL
TO THE SUPPORT

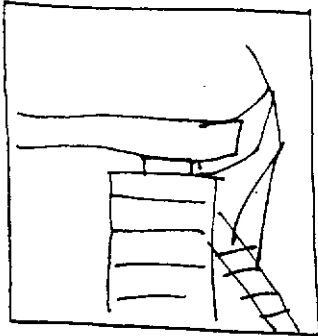


ON THE WALL.



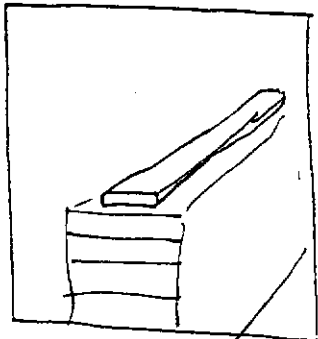
A BEAM
OR A BEAM-NET

SHOULD NOT BE POSED
DIRECTLY ONTO THE WALL.

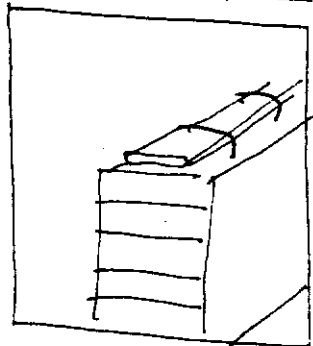


IT SHOULD REST
ON A LONG PIECE OF WOOD

WHICH DISTRIBUTES, LIKE A CUSHION
THE WEIGHT OF THE WALL.

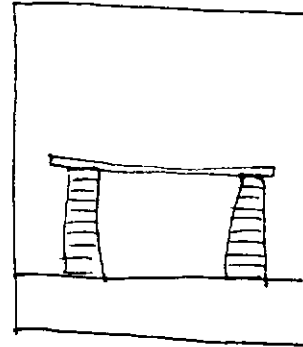


THOSE PIECES OF WOOD
DONT NEED TO BE STRONG,
AS THEY REST ON THE WALL
ALL THEIR LENGTH.

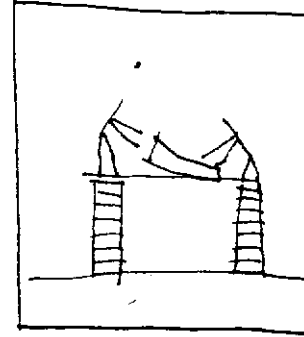


THEY WILL BE FASTENED
TO THE WALL,

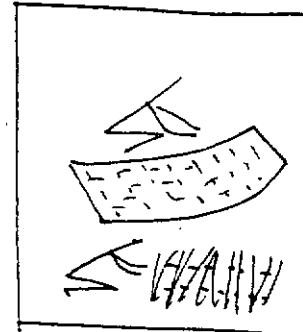
WITH IRON CLAMPS,
OR WITH BOWS
MADE IN BAMBOO OR IN TWIGS.



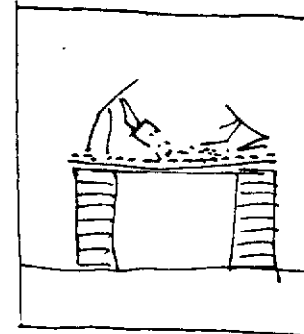
ONCE THE BEAMS, OR THE BEAM-NET
ARE FIXED



A COVER CAN BE POSED

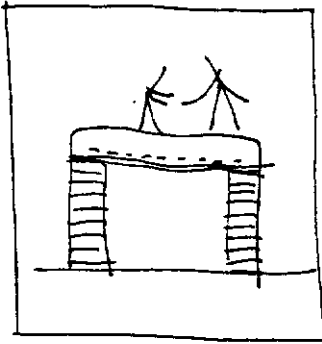


WHICH CAN BE MADE
WITH MATS,
TWIGS
OR OTHER SIMILAR MATERIAL.

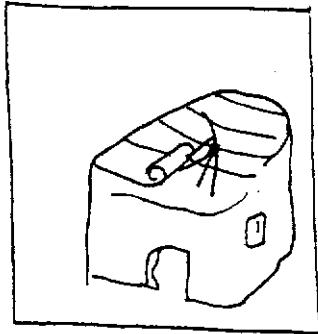


ON THAT COVER
SHOULD BE SMEARED
A THICK LAYER OF MUD,

WHICH SEALS THE INTERSTICES
IN THE MAT,
AND MAKES THE ROOF MORE SOLID.

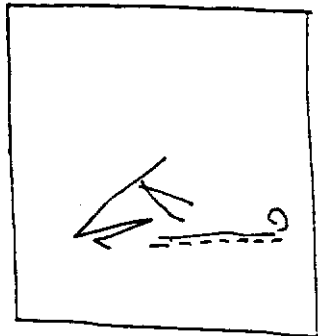


THIS ROOF IS GOOD,
BUT STILL NOT WATERPROOF.



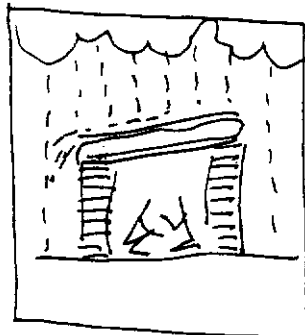
YOU SHOULD THEREFOR COVER IT
WITH WATERTIGHT MATERIAL:

ALUMINIUM FOIL,
PLASTIC FOIL
OR SIMILAR.



THIS KIND OF MATERIAL
CAN BE FIXED
BY GLUE ON MATS,

LAI D ON THE TOP OF THE ROOF.



IT IS ADVANTAGEOUS
TO HAVE THE WHOLE ROOF
TILTED AT A GENTLE SLOPE,

TO ALLOW THE WATER
TO RUN OFF.



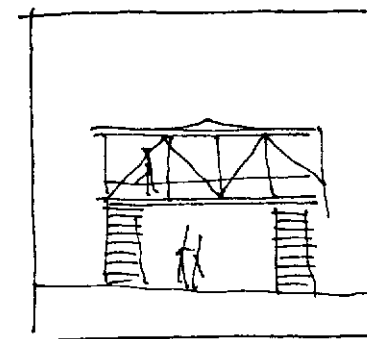
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

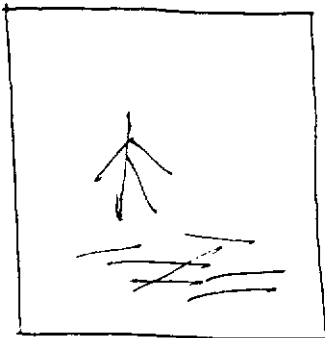


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

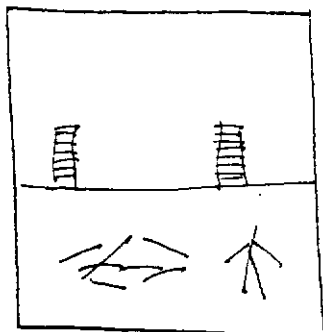
33, BD GARIBOLDI, 75015 PARIS ☎ (331) 763-20-24

SPACE-FRAMES

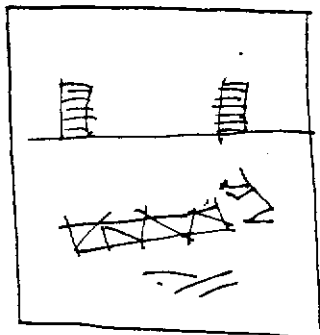




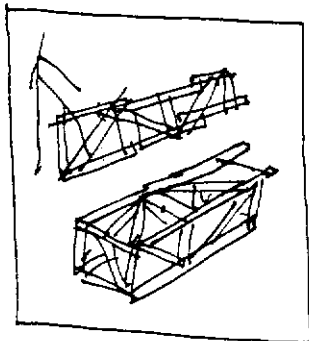
IF YOU ONLY DISPOSE
OF SMALL LENGTHS OF WOOD
TO BUILD YOUR ROOF



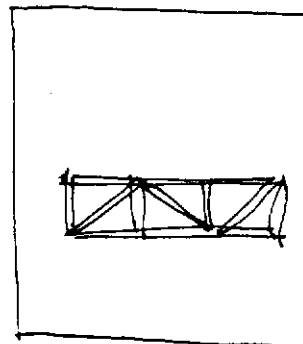
YOU CAN BUILD A STRUCTURE
SOLID ENOUGH
EVEN FOR A LARGE SPAN.



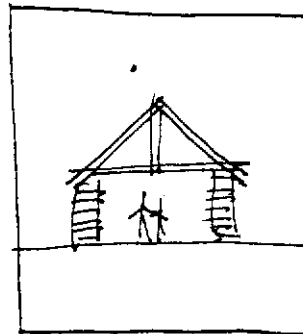
FOR THIS PURPOSE,
YOU SHOULD MAKE, WITH THAT WOOD,
TRUSSES,



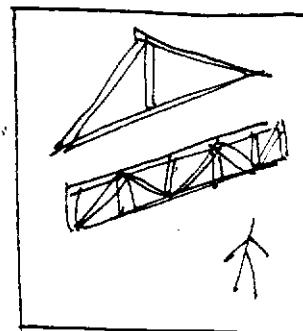
EITHER PLAIN ONES
OR SPACE-FRAMES.



A TRUSS LOOKS
LIKE A SORT OF A GRID
WITH TRIANGULAR HOLES.

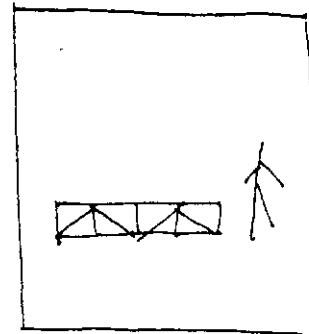


THE SIMPLEST TRUSS
IS THAT
USED FOR TRADITIONAL ROOFS



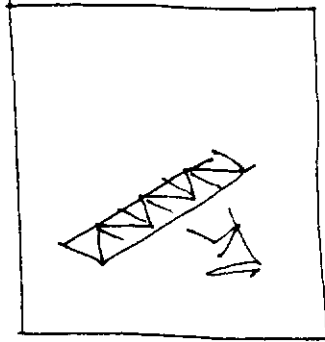
IN MANY REGIONS.

TRUSSES WITH MORE MASHES

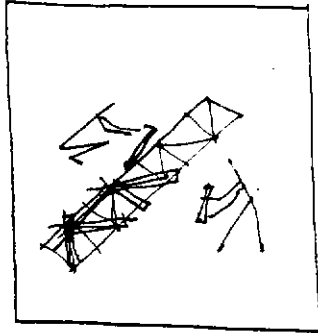


NEED SHORTER PIECES OF WOOD
THAN DO TRADITIONAL ROOFS.

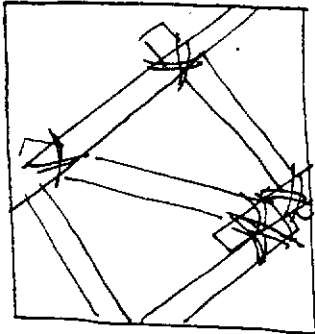
BESIDE THAT,
SUCH TRUSSES DON'T NEED TO BE
VERY HIGH.



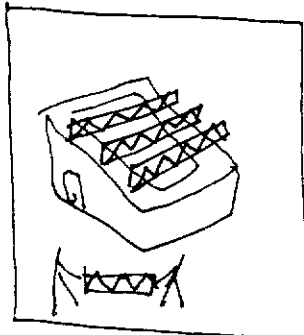
TO COMPOSE SUCH TRUSSES
FIRST YOU HAVE TO DRAW
THE PATTERN ON THE GROUND.



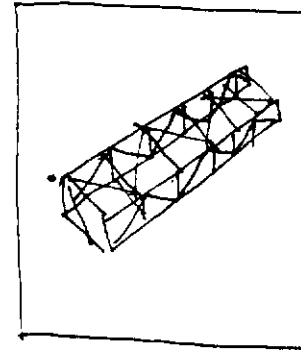
THEN, ADJUST THE APPROPRIATE
PIECES OF WOOD
TO THE DRAWING,



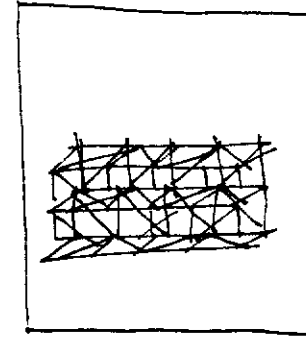
AND TIE TOGETHER THOSE PIECES
WITH A VERY SOLID ROPE.



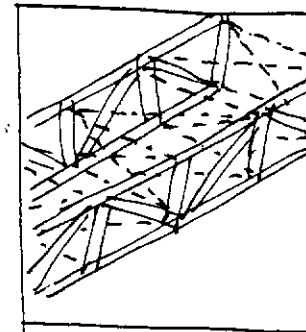
THEN YOU CAN LIFT UP
THE STRUCTURE
AND USE IT AS
AN ORDINARY BEAM.



SPACE FRAMES
ARE NOT VERY DIFFERENT
FROM ORDINARY TRUSSES.

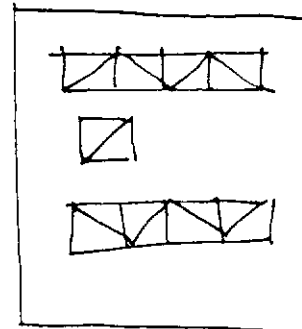


YOU CAN MAKE A SPACE FRAME TRUSS
BY FIXING TOGETHER
SEVERAL PLANE TRUSSES,

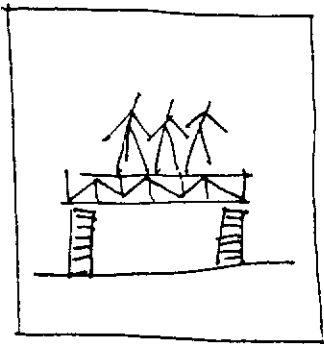


LINKING THEM
WITH APPROPRIATE PIECES OF WOOD.

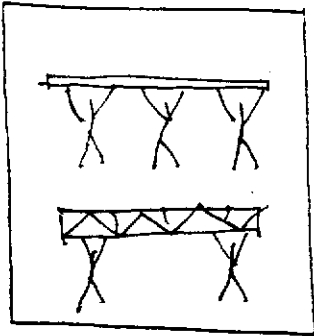
THE LINKAGE SHOULD BE MADE SO
THAT NEW TRIANGLES ARE FORMED



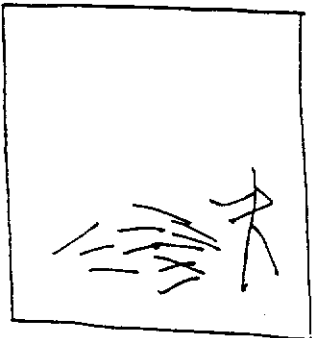
IN ALL THE PLANES.



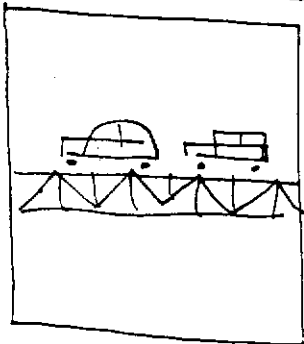
SPACE FRAME TRUSSES
ARE VERY STRONG



AND THEY WEIGH LESS
THAN FULL BEAMS DO.

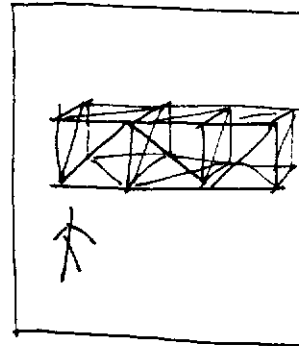


THEY CAN BE BUILT
WITH VERY SMALL PIECES OF WOOD

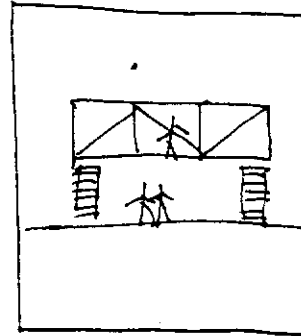


AND BEAR THE LOAD
THAT A FULL BEAM WOULD BEAR.

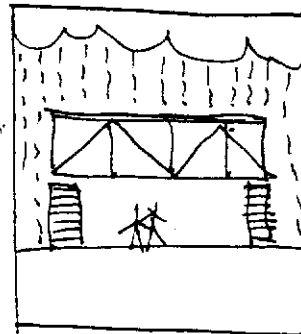
IT IS LIKE A BRIDGE.



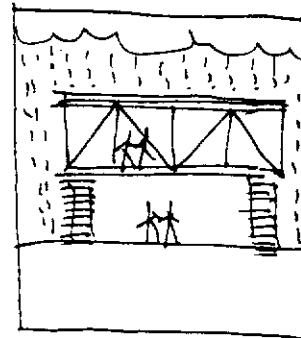
IF SUCH SPACE FRAME TRUSS
IS MADE HIGH ENOUGH
FOR A MAN STAND UP INSIDE,



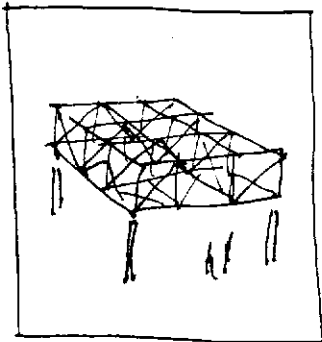
IT CAN FORM
AN ADDITIONAL STOREY
TO THE HOUSE.



INDEED,
THE COVER CAN BE FIXED
ON THE UPPER RIM OF THE TRUSS,



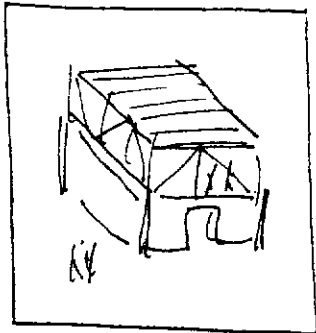
AND A FLOOR
ON ITS BOTTOM RIM.



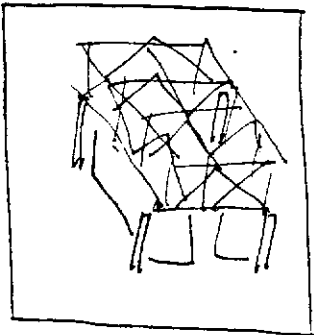
SUCH A SPACE FRAME STRUCTURE
DOES NOT NEED MANY SUPPORTS,

EVEN FOR A LARGE AREA,

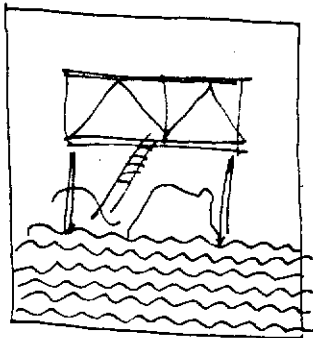
IT DOES NOT NEED TO
ON THE WALLS EITHER,



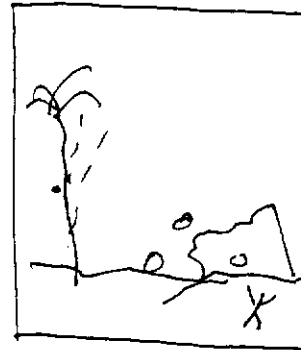
4 POSTS ARE ENOUGH TO BEAR IT.



IF THESE POSTS ARE SOLID,
THE ROOF
WILL STAND EVEN IF THE WALLS CRUMBLE

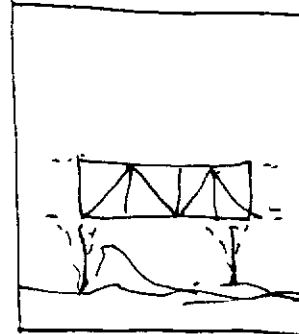


(FOR EXEMPLE, IN CASE OF FLOOD).



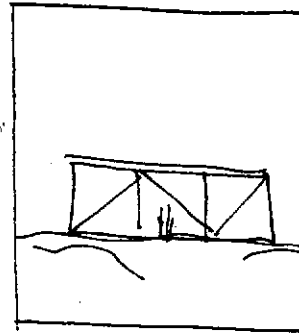
A SPACE FRAME STRUCTURE
~~OF~~ THIS KIND
IS EARTHQUAKE SAFE,

AS IT DOES NOT BREAK WHEN TREMBLING
TO MAKE IT COMPLETELY SAFE,

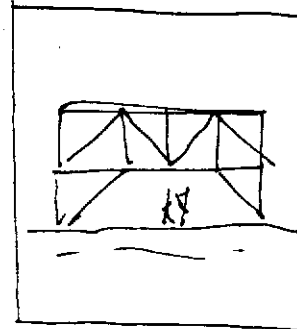


IT SHOULD NOT REST ON
ORDINARY POSTS (WHICH COLLAPSE).

IT CAN REST DIRECTLY
ON THE GROUND,
WITHOUT FOUNDATIONS,



OR BE SUPPORTED
BY PYRAMID-LIKE PILLARS,
SOLIDLY TIED TO IT.



IT WILL BE, THEN, AS SOLID,
AS A TABLE, WHICH DOES NOT BREAK
WHEN MOVED.



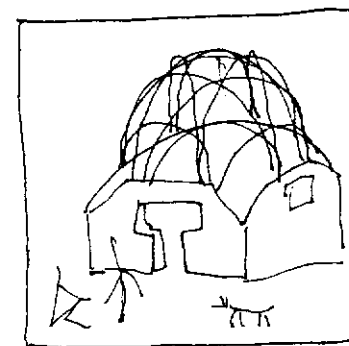
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



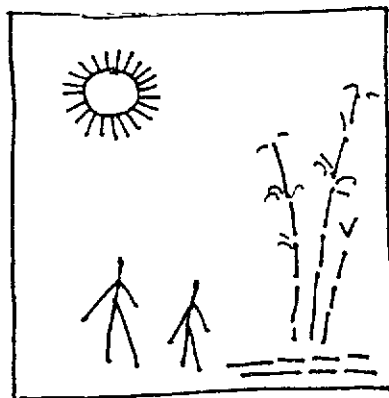
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BD GARIBALDI, 75015 PARIS ☎ (331) 783-20-24

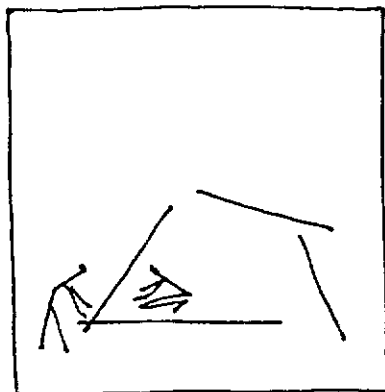
BAMBOO DOMES
WITH SUSPENDED MAT COVER



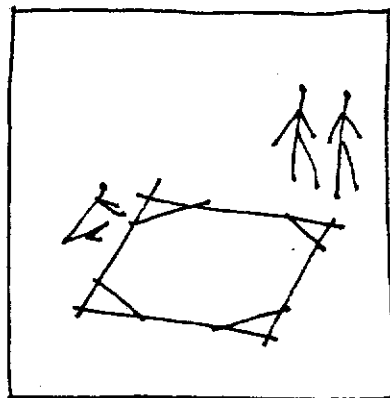
BASIC RESEARCH: YONA FRIEDMAN, EDA SCHAUR, CCSK



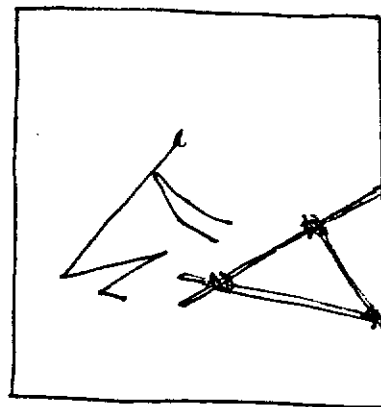
TO MAKE A CHEAP
AND EFFICIENT ROOF
OUT OF BAMBOO



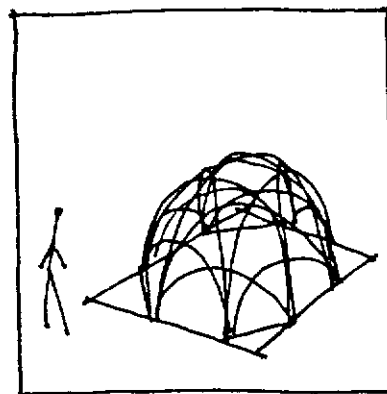
WE STARTED
BY MAKING A FRAME:



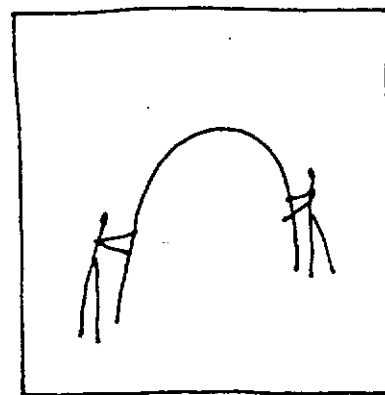
A SQUARE
WITH DIAGONAL BRACING
NEAR TO ITS CORNERS.



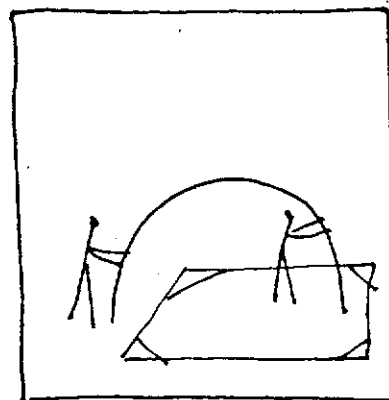
THIS FRAME,
MADE OF BAMBOO
OR OF CASUERINA,
WAS MADE OF RODS
FIXED TOGETHER BY ROPES.



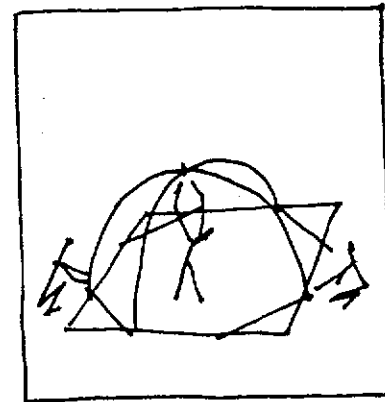
ON THIS FRAME AS A BASIS
WE ERECTED A DOME,



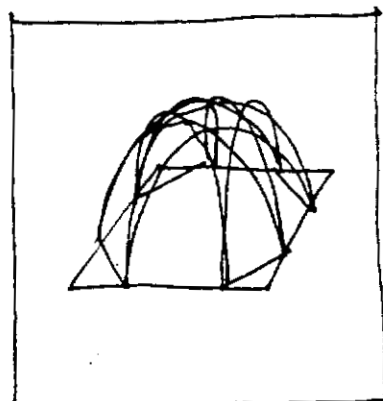
BY MAKING ARCHES
OUT OF SPLIT BAMBOO
OR OF FULL ROUND BAMBOO.



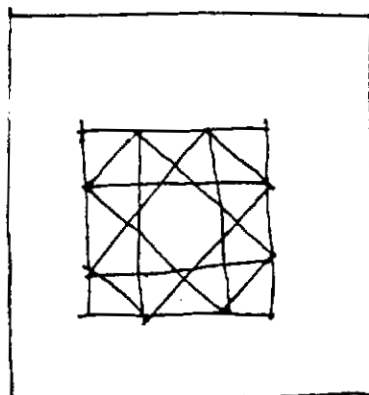
THESE ARCHES
WERE ABOUT AS HIGH
AS THE HALF OF ONE SIDE
OF THE FRAME.



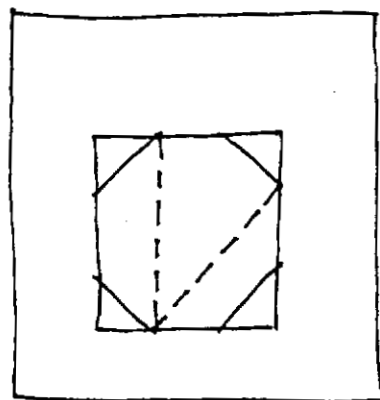
WE FIXED THEM
STANDING UP
BETWEEN CORNERS
OF THE FRAME,
IN VARIOUS PATTERNS.



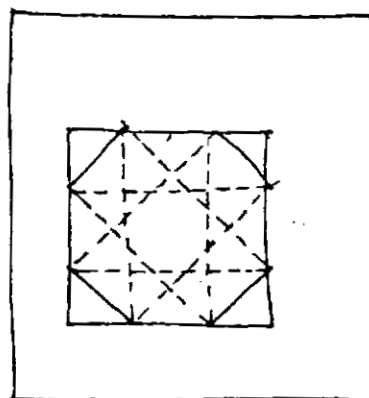
SUCH ARCHES
CAN BE LAID OUT
ON THE FRAME
IN MANY WAYS:



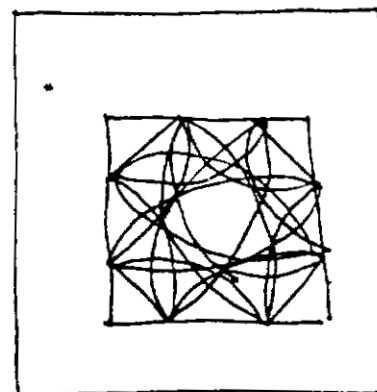
LIKE THIS,



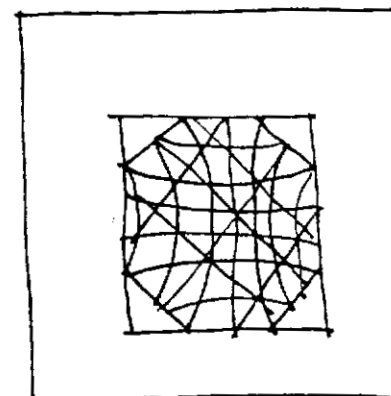
WHERE THEY LINK
EACH CORNER OF THE FRAME
TO THE OTHER
3 MODULES AWAY.



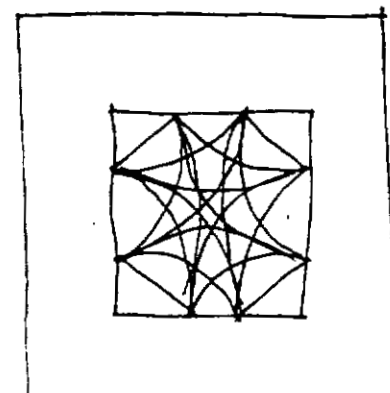
WE REPEAT THIS OPERATION
FROM EACH CORNER



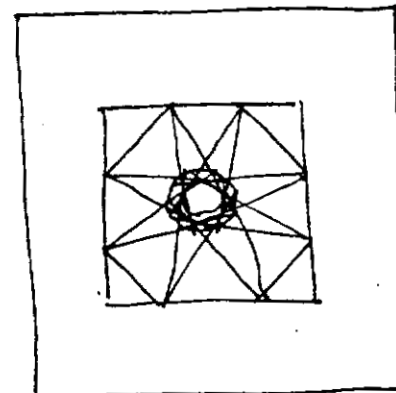
THERE ARE
MANY OTHER PATTERNS.
LIKE THIS ONE,



OR THIS ONE,
(WHERE SOME ARCHES
START FROM THE SIDES
OF THE SQUARE
AND NOT FROM
THE CORNERS).

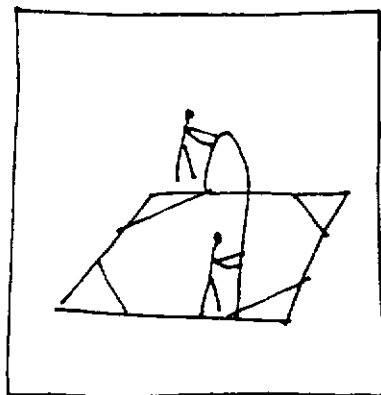


OR THIS ONE

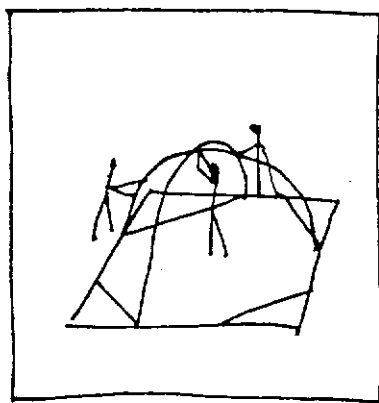


AND MANY MORE.

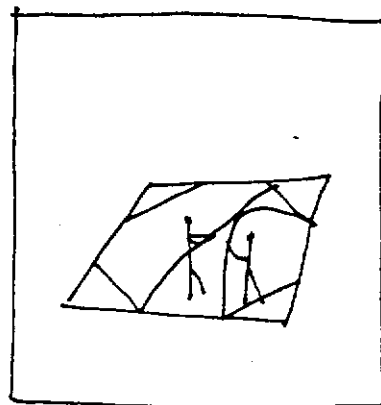
WE MADE USE
FOR THIS MUSEUM
OF 6 DIFFERENT PATTERNS.



TO MAKE SURE
THAT THE ASSEMBLED ARCHES
KEEP STANDING UP
FROM THE START,

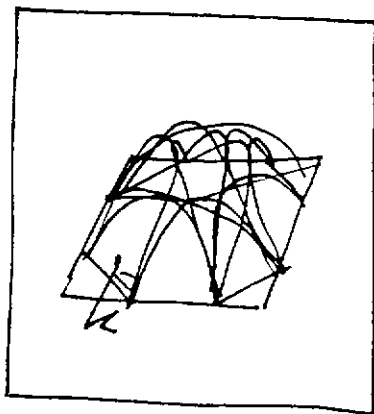


WE CHOOSE TO START
WITH THOSE 2 ARCHES
WHICH FORM A CROSS,
ON THE OCTAGON
OF THE FRAME,

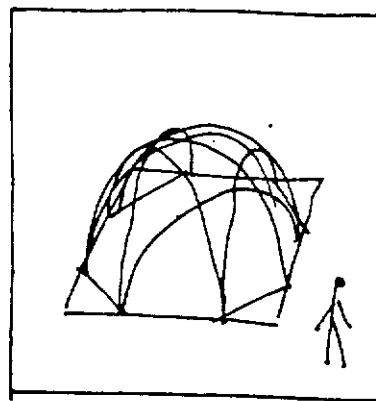


OR, IN ANOTHER PATTERN,
THOSE WHICH LEAN ON
EACH OTHER,

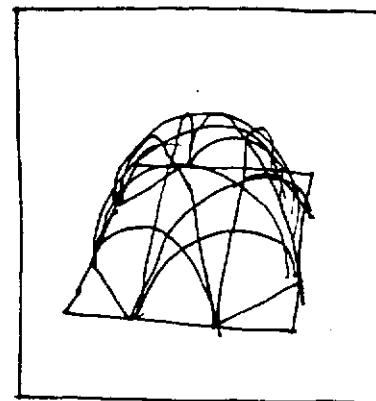
AND WE TIED TOGETHER
THESE 2 ARCHES.



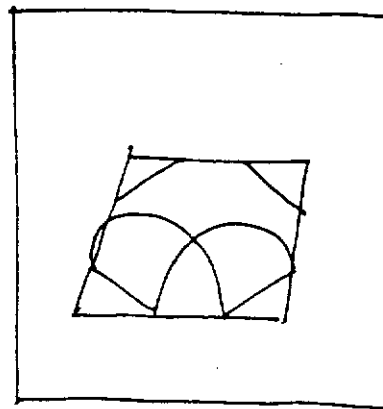
THEN WE REPEATED
THIS OPERATION
STARTING, ONE AFTER THE OTHER,
AT EACH CORNER OF THE FRAME.
ALL 8 COUPLES OF ARCHES
WERE, AT THE END,
TIED TOGETHER.



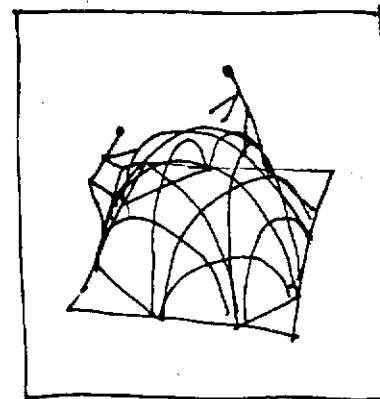
ONCE THESE MAIN ARCHES
FORMED THE DOME-SHAPE
WE WANTED



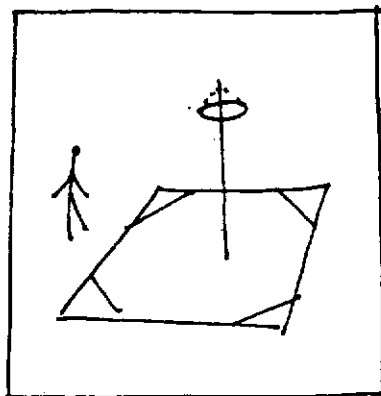
WE HAD TO FIX THAT SHAPE.
SO WE MADE 8 OTHER ARCHES,
HALF AS HIGH AS THE MAIN ONES,
EACH STARTING FROM
A CORNER OF THE FRAME



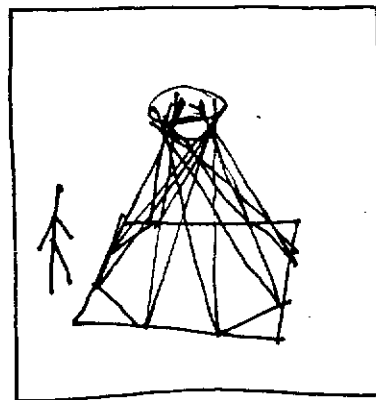
LINKING IT
TO THE AFTER-NEXT ONE.



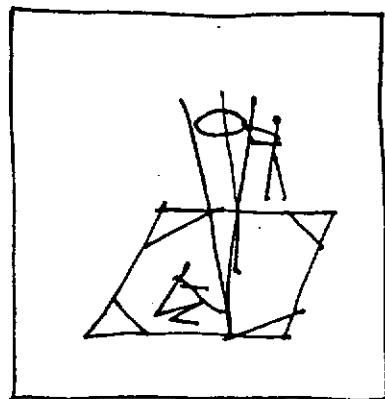
AT THIS STAGE
THE DOME STRUCTURE
BECAME STABLE.



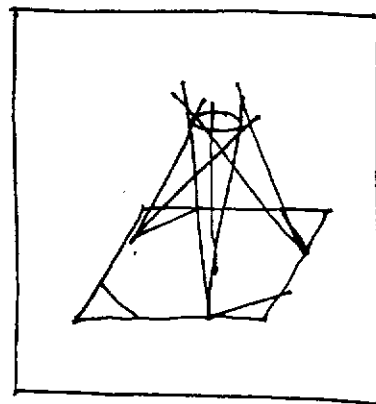
ANOTHER TYPE OF DOME
WE STARTED WITH A RING
FIXED ON A POLE



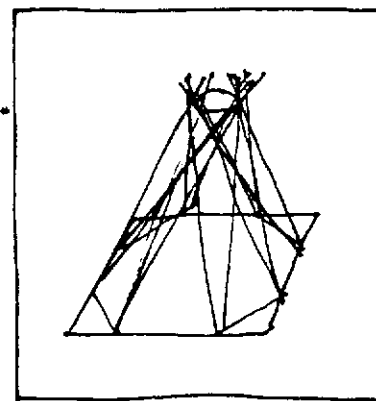
AS HIGH
AS THE DOME SHOULD BE



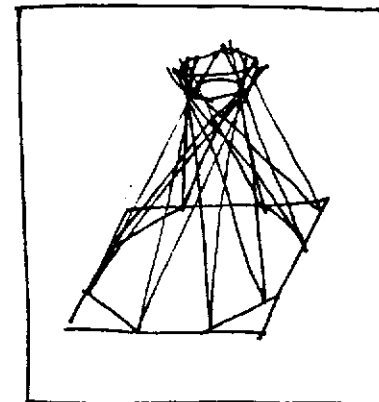
WE TIED TO THAT RING
TWO BAMBOO RODS
LINKING IT TO A CORNER
OF THE FRAME SO
THAT THEY SHOULD TOUCH
THE RING ON OPPOSITE SIDES,



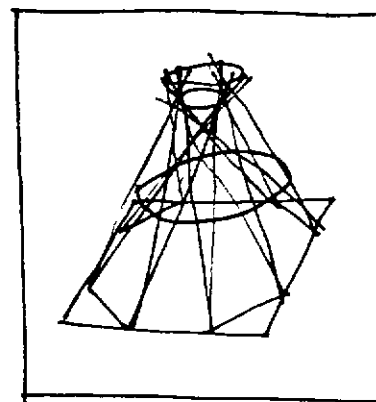
AND WE REPEATED THIS
FROM EACH CORNER
OF THE FRAME.



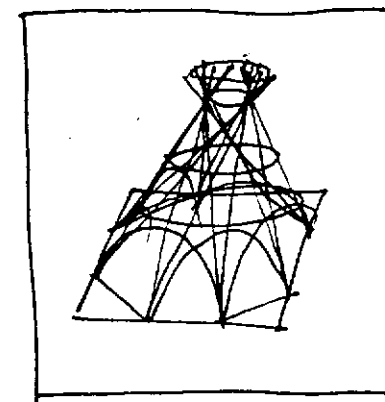
WE STIFFENED THAT DOME,
ONCE ALL THE RIBS
WERE IN PLACE,



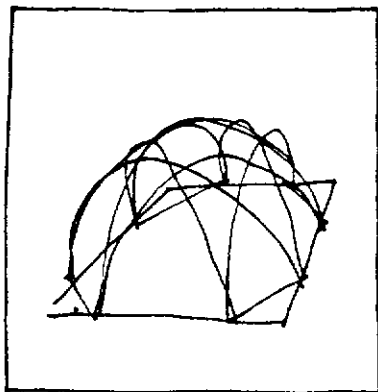
WITH BAMBOO RINGS
AT VARIOUS HEIGHTS:
ONE AT THE TOP,



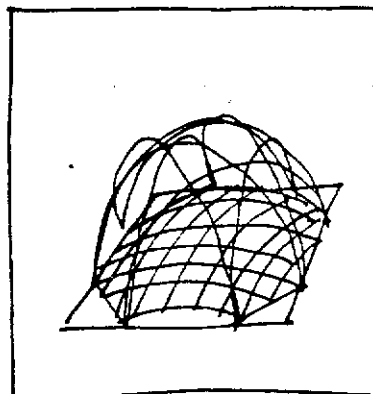
ANOTHER AT MID-HEIGHT,
AND SO ON.



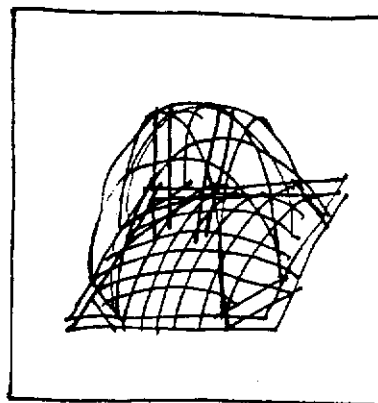
ONCE WE FINISHED ALL THESE,
WE MADE LOW ARCHES
BETWEEN CORNERS OF THE FRAME
AND TIED THESE ARCHES
TO THE RIBS.



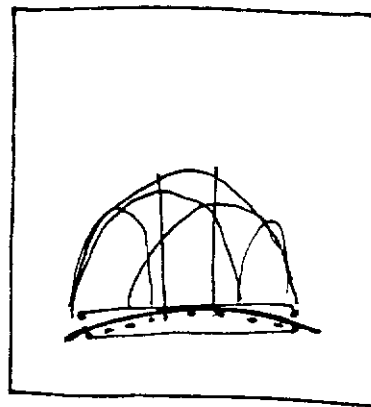
THESE DOME STRUCTURES
ARE USED TO SUPPORT



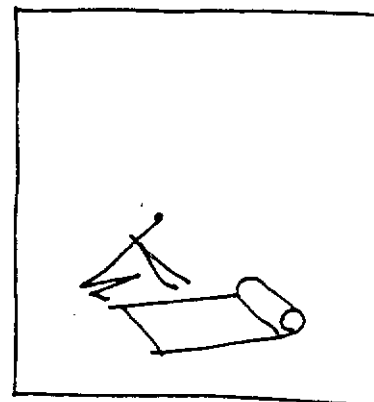
A LIGHT LOWER DOME
WHICH IS MORE FLAT,



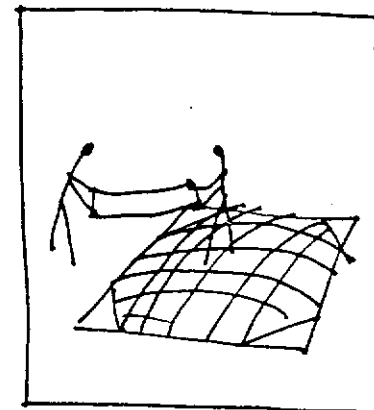
AND WHICH IS BASTENED
ON ANOTHER FRAME,
AND WHICH HANGS
ON 4 WIRES FROM
THE UPPER DOME.



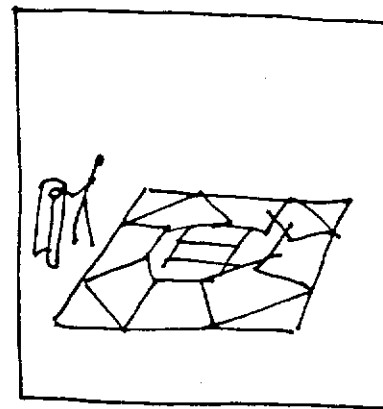
THE LOWER DOME
IS THE SUPPORT
OF THE ROOF CLADDING.



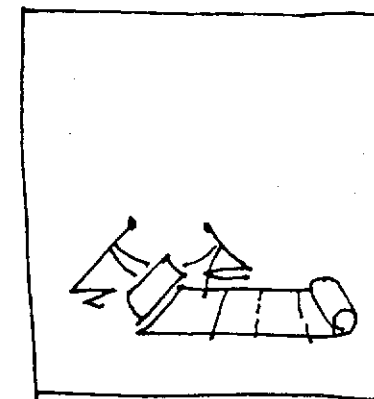
WE MADE THE ROOF CLADDING
WITH BAMBOO MATS



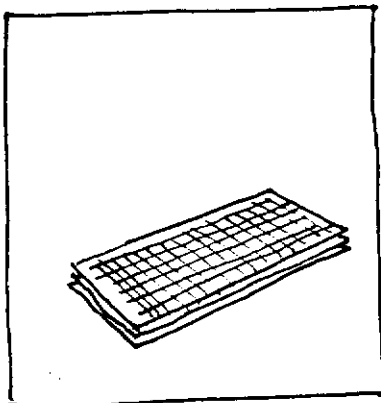
A FIRST LAYER OF WHICH
WAS POSED ON THE GRID
OF THE LOWER DOME.



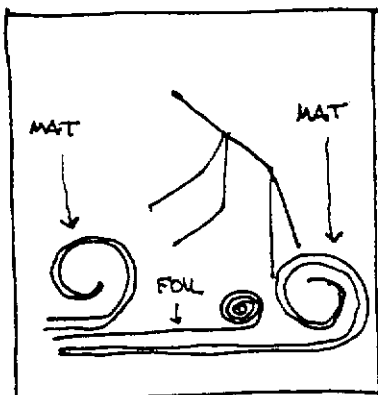
FOR THE SECOND LAYER
WE PREPARED OTHER MATS



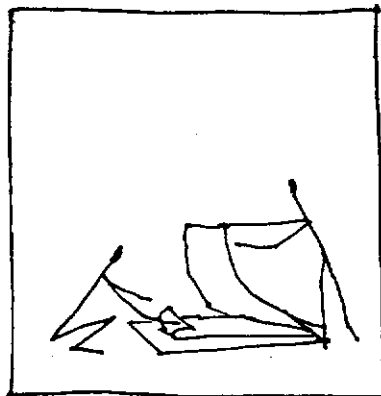
ON WHICH WE PREVIOUSLY
GLUED THIN ALUMINUM FOL
(ON THEIR UPPER SIDE).



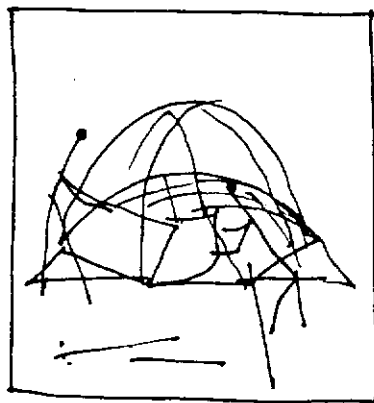
ANOTHER KIND OF CLADDING
(ALSO WITH ALUMINUM FOIL)



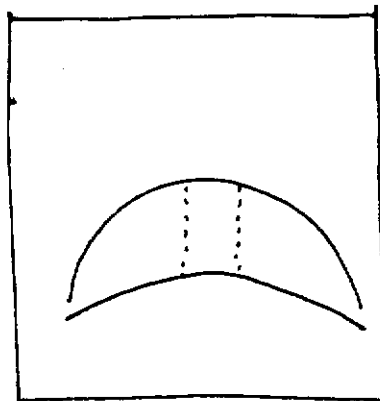
CAN BE MADE
BY FIXING THE FOIL
BETWEEN 2 BAMBOO MATS
(WHICH PROTECT THIS)
THE FOIL).



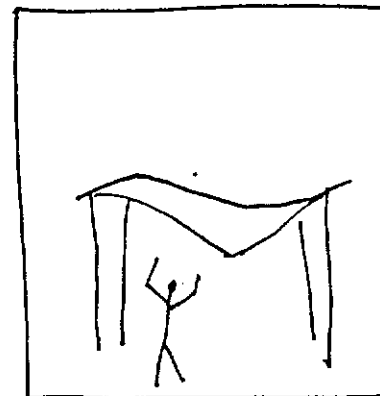
SUCH "SANDWICH" MATS
WE PREPARED
ON THE GROUND,



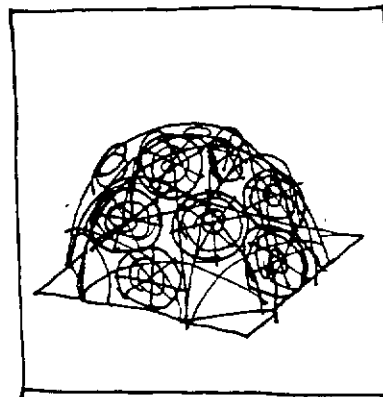
THEN WE FIXED THEM
ON THE LOWER DOME,
AS WE DID
WITH THE ORDINARY MATS.



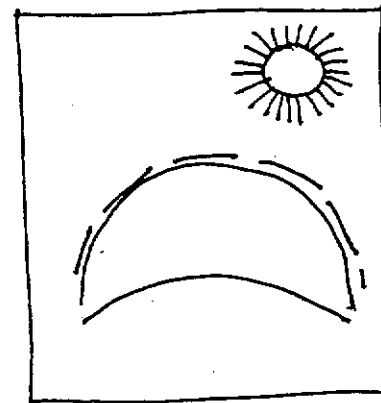
THE UPPER DOME
HAS A DOUBLE TASK:
TO SUPPORT THE LOWER DOME
WHICH HANGS ON IT



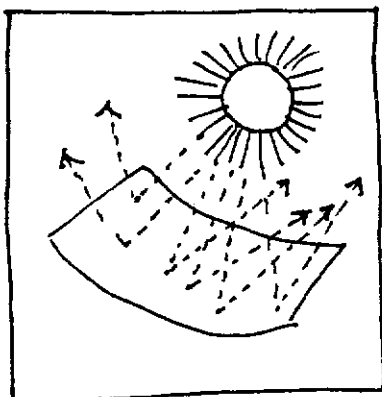
AND WHICH WOULD COLLAPSE
WITHOUT THAT SUPPORT;



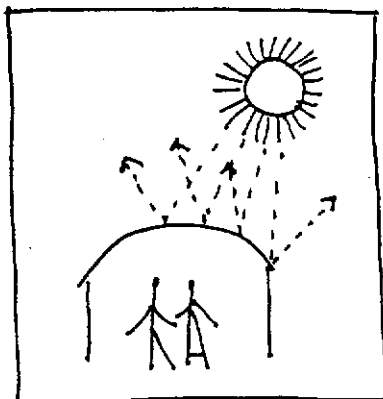
AND A SECOND TASK:
THE UPPER DOME
IS COVERED
WITH FLAT ROUND BASKETS



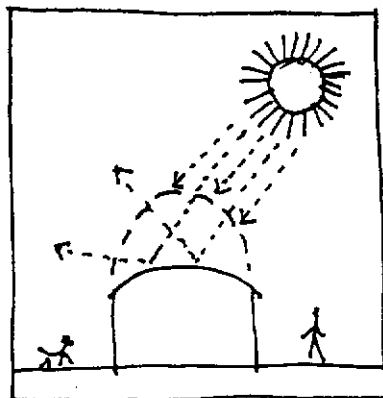
WHICH CAST A HALF-SHADOW
ONTO THE LOWER DOME,
KEEPING ITS SHELL COOLER.



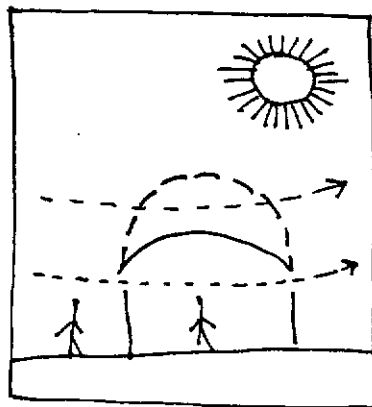
THE ALUMINIUM FOIL
HAS THE PROPERTY
TO REFLECT HEAT.



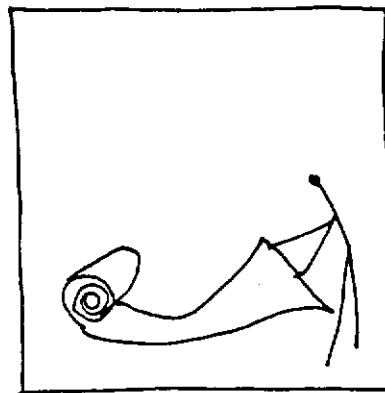
THUS IT HELPS
TO KEEP COOLER THE ROOM
UNDER THE SHELL.



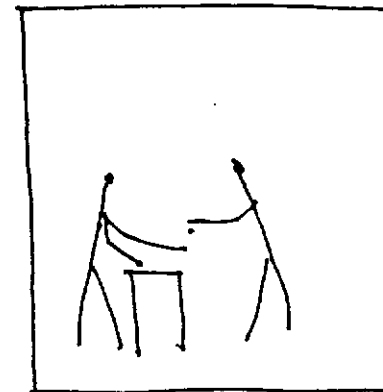
THE HALF-SHADOW
CAST BY THE UPPER DOME
INCREASES
THE COOLING EFFECT



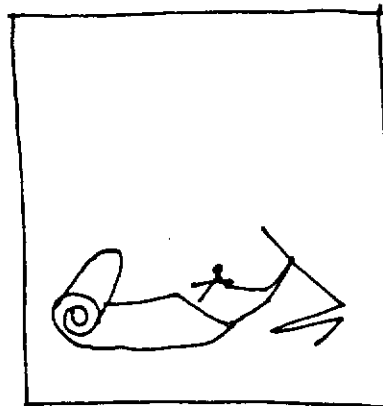
AND THE AIR CURRENT
WHICH CAN PASS
UNDER BOTH DOWES,
ADDS TO THAT EFFECT TOO.



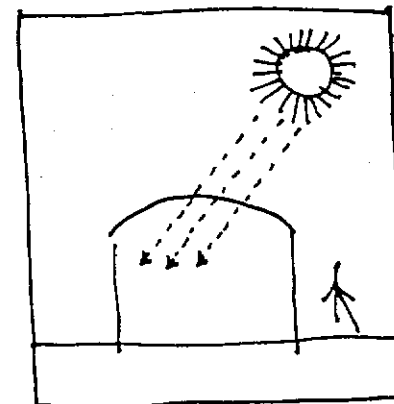
ONE CAN USE PLASTIC FOLLS
INSTEAD OF ALUMINIUM.



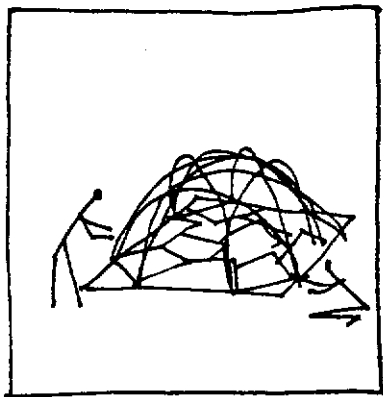
IT IS CHEAPER (SOMEWHAT)
AND EASIER TO OBTAIN



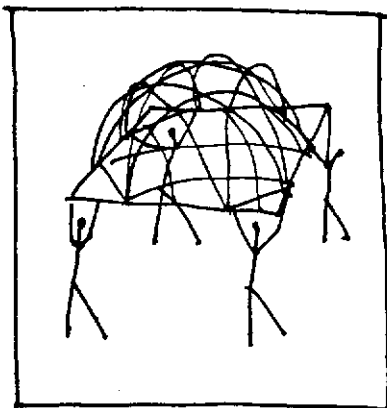
IT MIGHT BE EASIER
TO WORK WITH THEM TOO,



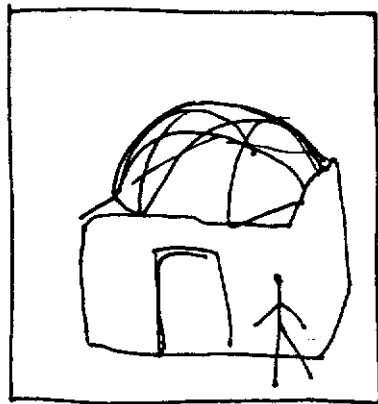
BUT THEIR COOLING CAPACITY
IS MUCH LESS.



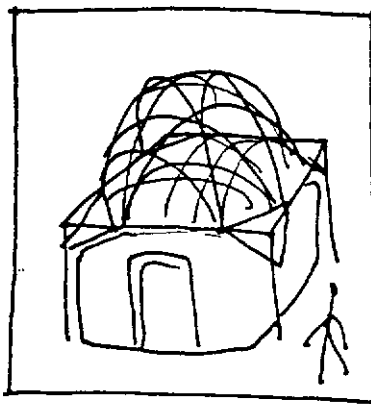
WHEN YOU HAVE FINISHED
TO BUILD THAT KIND OF ROOF
ON THE GROUND



YOU CAN LIFT IT
INTO ITS PLACE
AS A WHOLE.
4-6 PEOPLE
LIFT IT WITH EASE.

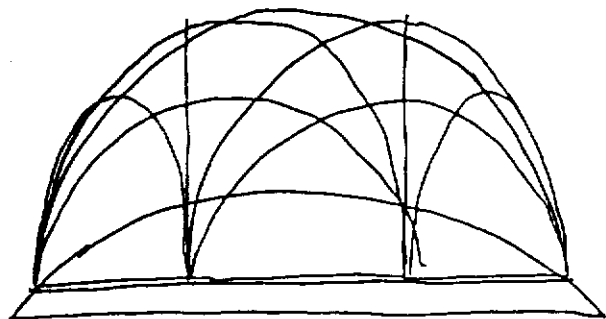


THAT ROOF CAN REST
ON THE WALL

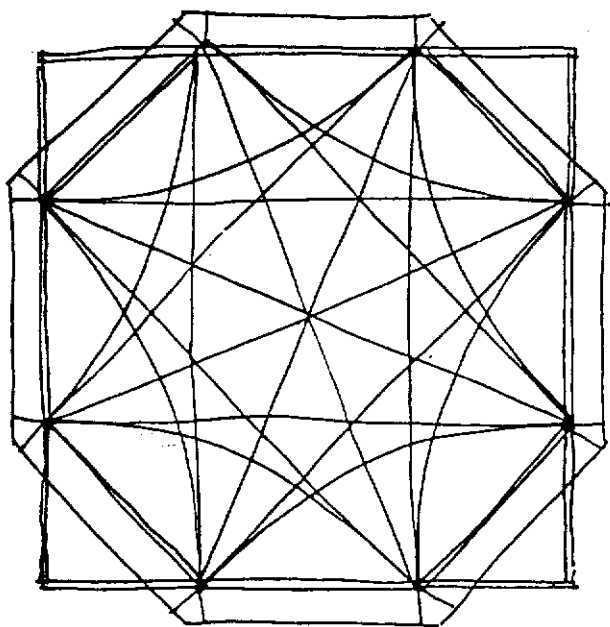


BUT IT MIGHT BE BETTER
IF IT WERE SUPPORTED
BY 4 POSTS OF BAMBOO
OR OF CASUARINA.

UPPER DOME

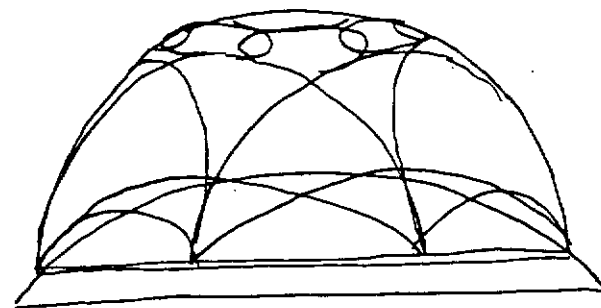


ELEVATION

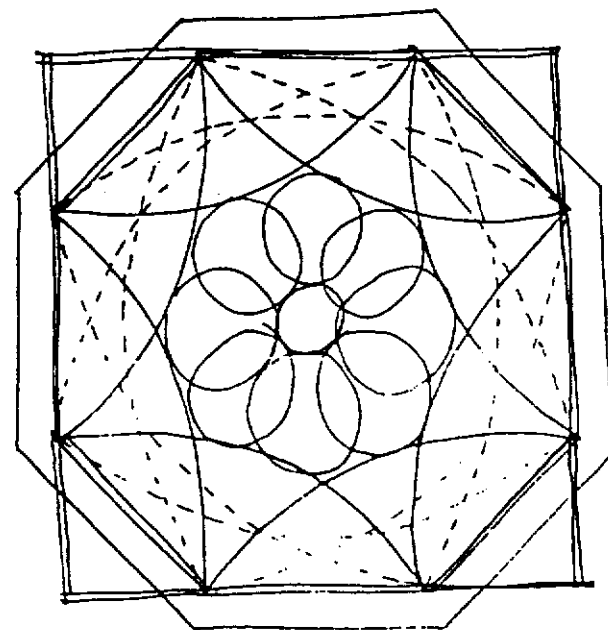


PLAN

UPPER DOME

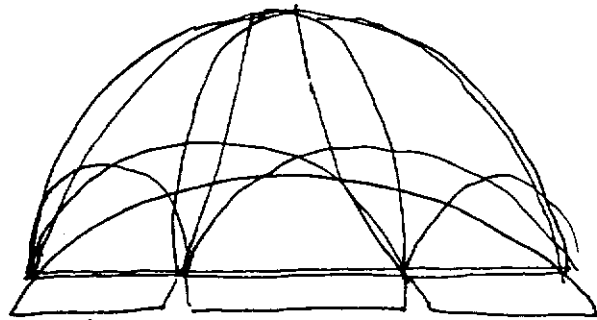


ELEVATION

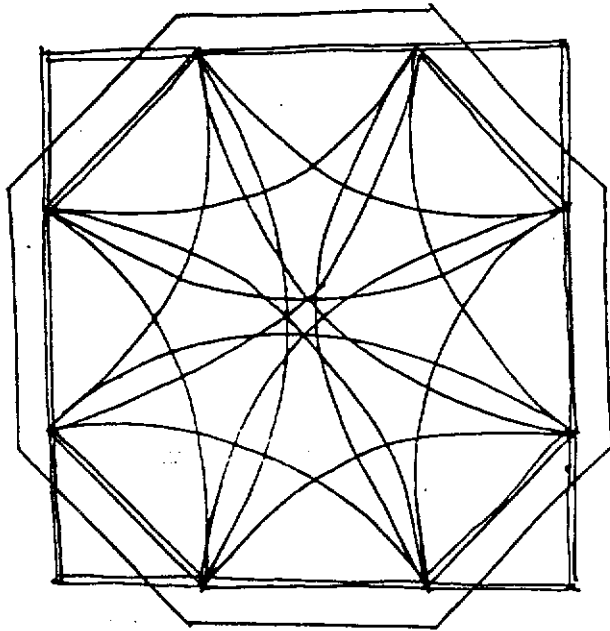


PLAN

UPPER DOME

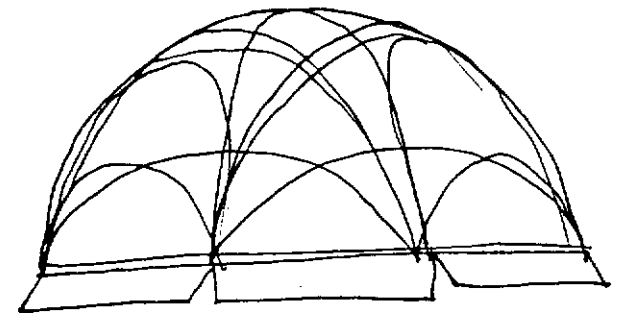


ELEVATION

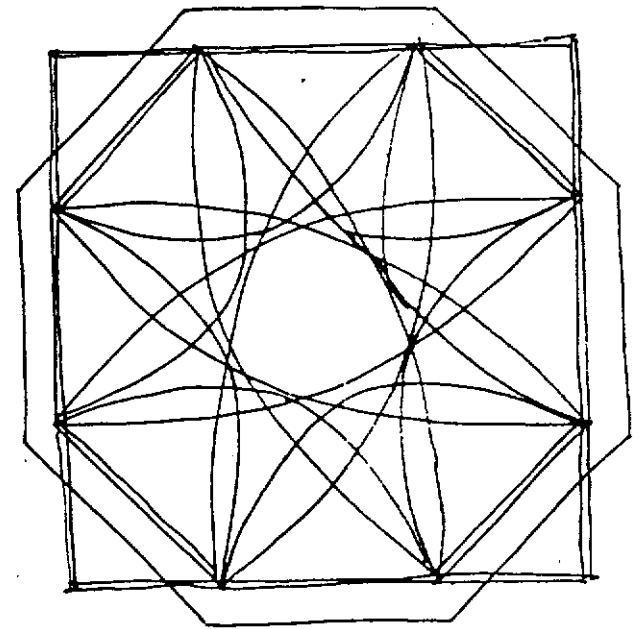


PLAN

UPPER DOME

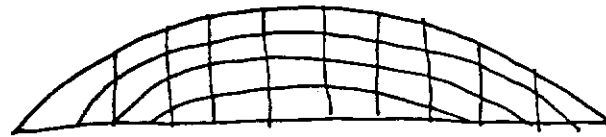


ELEVATION

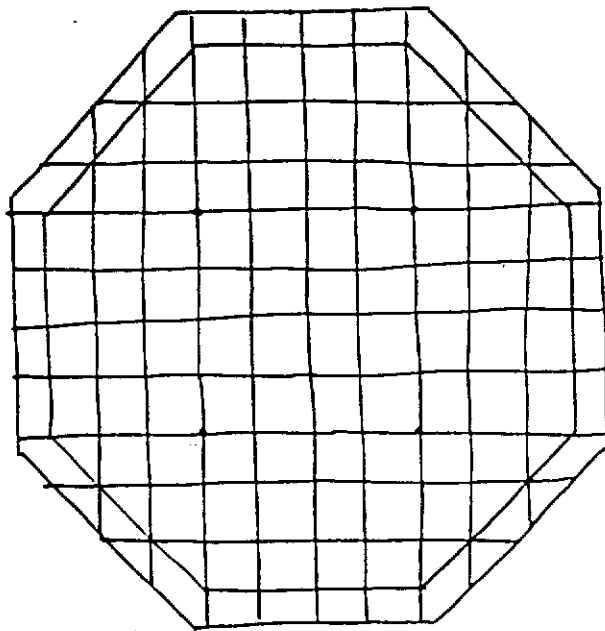


PLAN

LOWER DOME

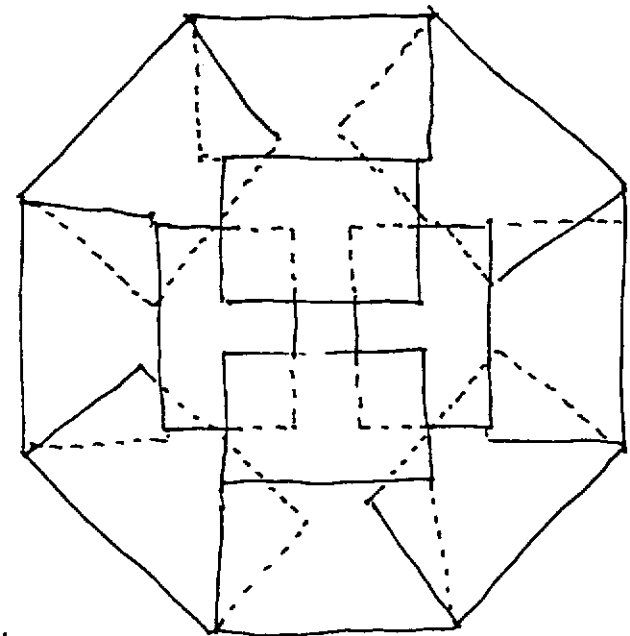


ELEVATION



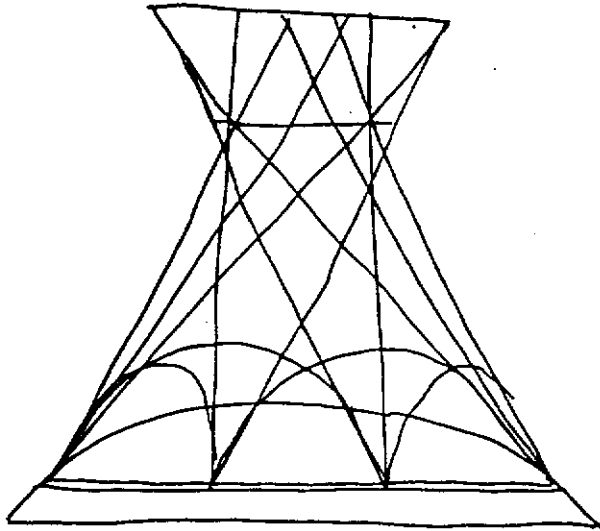
PLAN

DISTRIBUTION OF ALUMATS

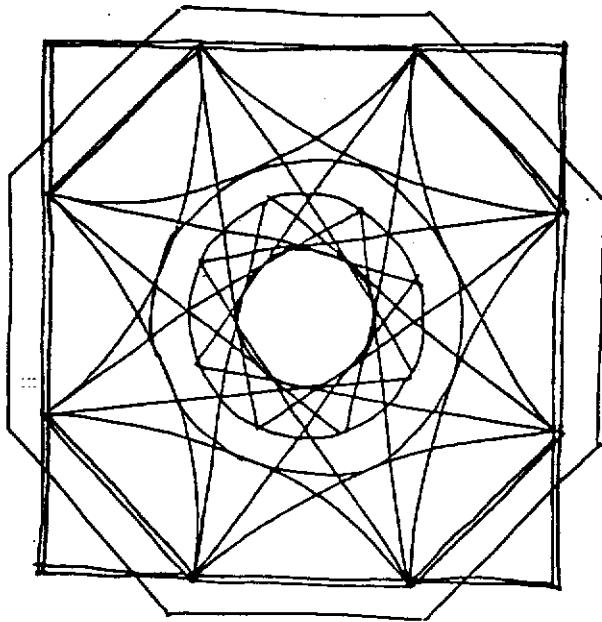


PLAN

UPPER DOME

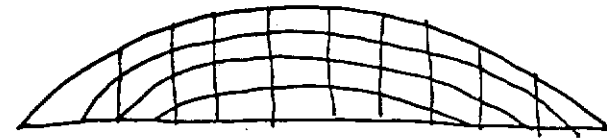


ELEVATION

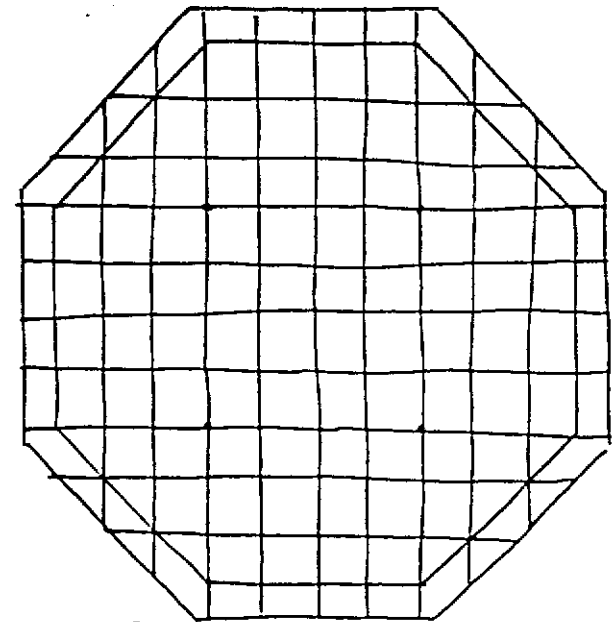


PLAN

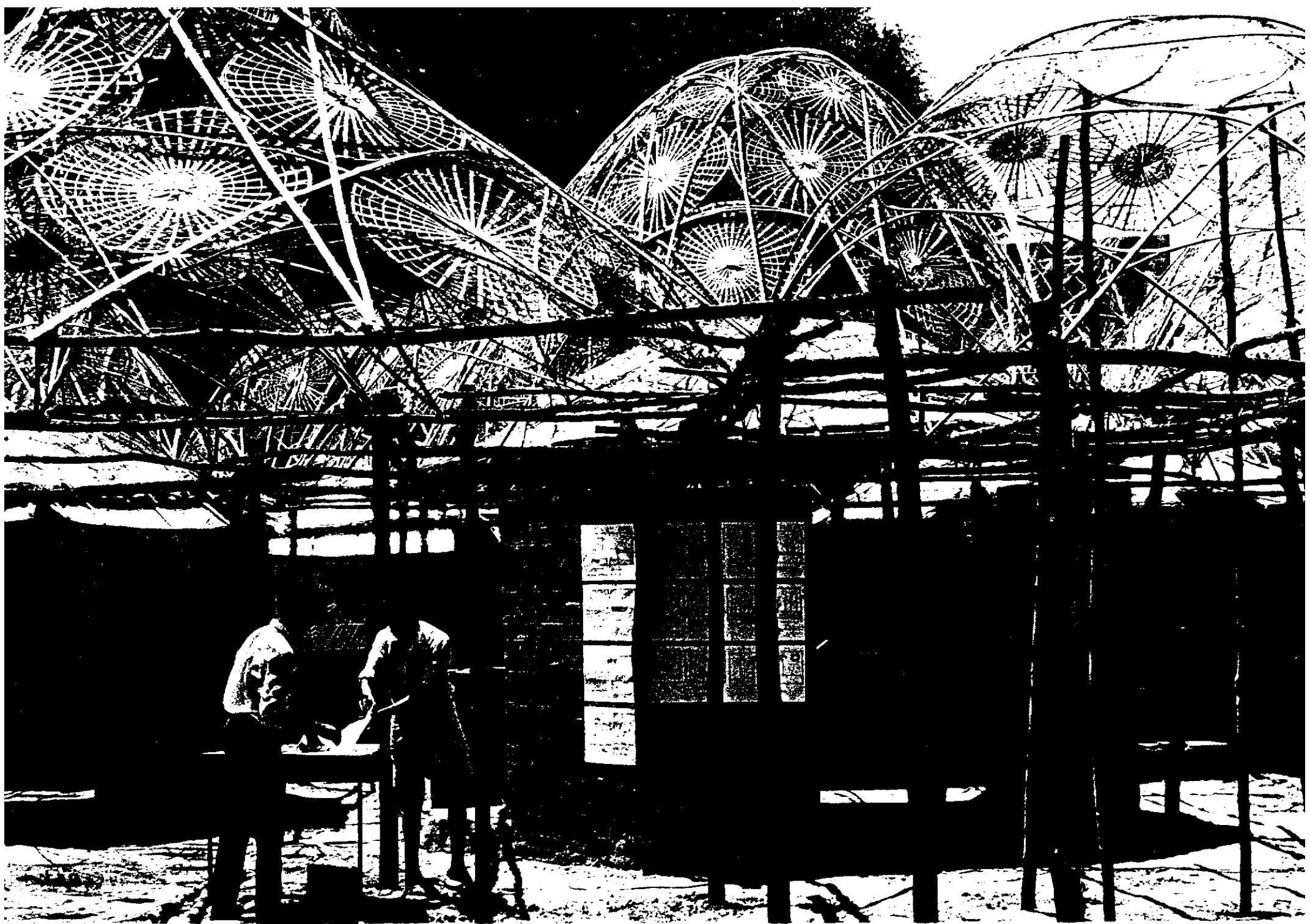
LOWER DOME



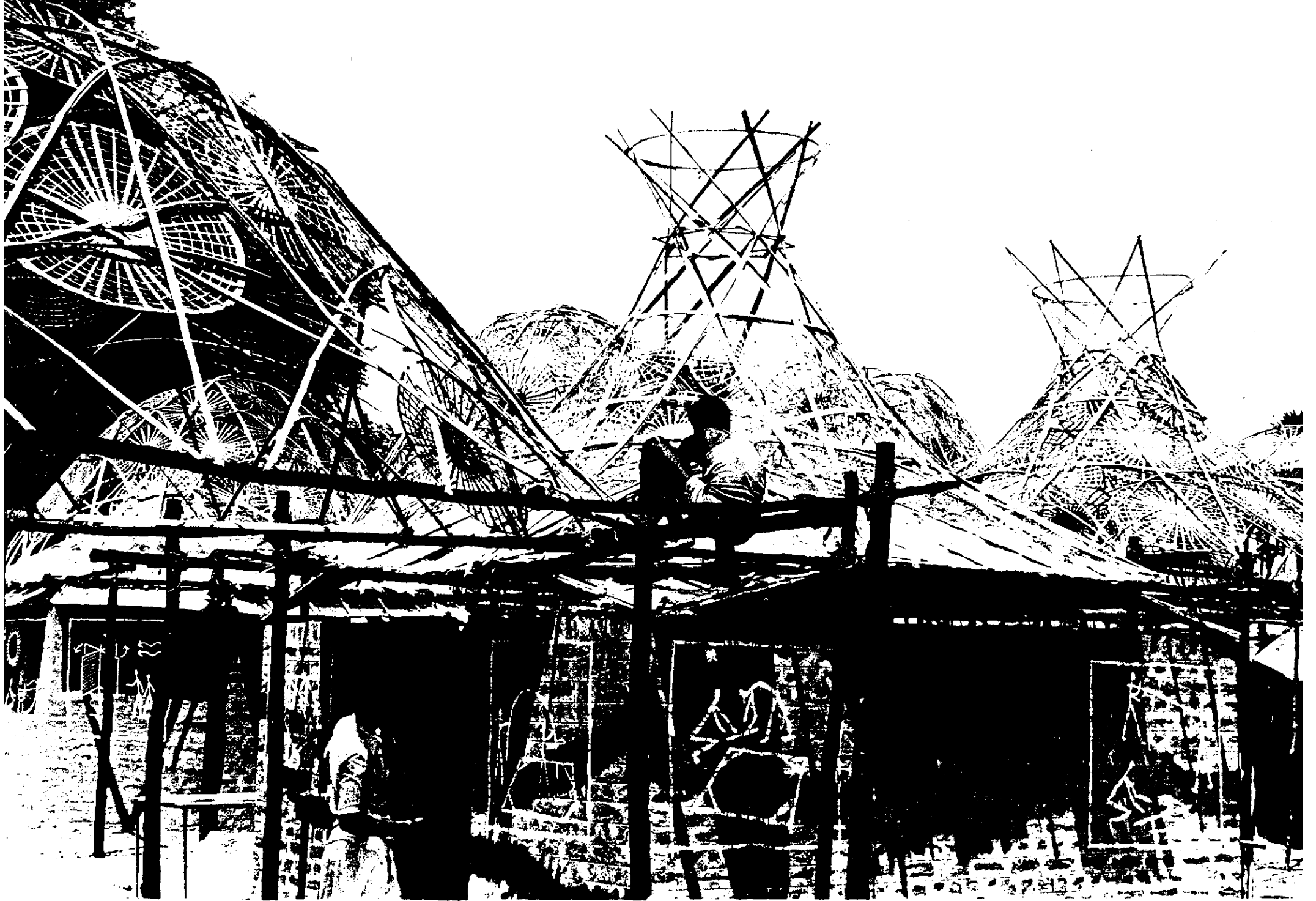
ELEVATION

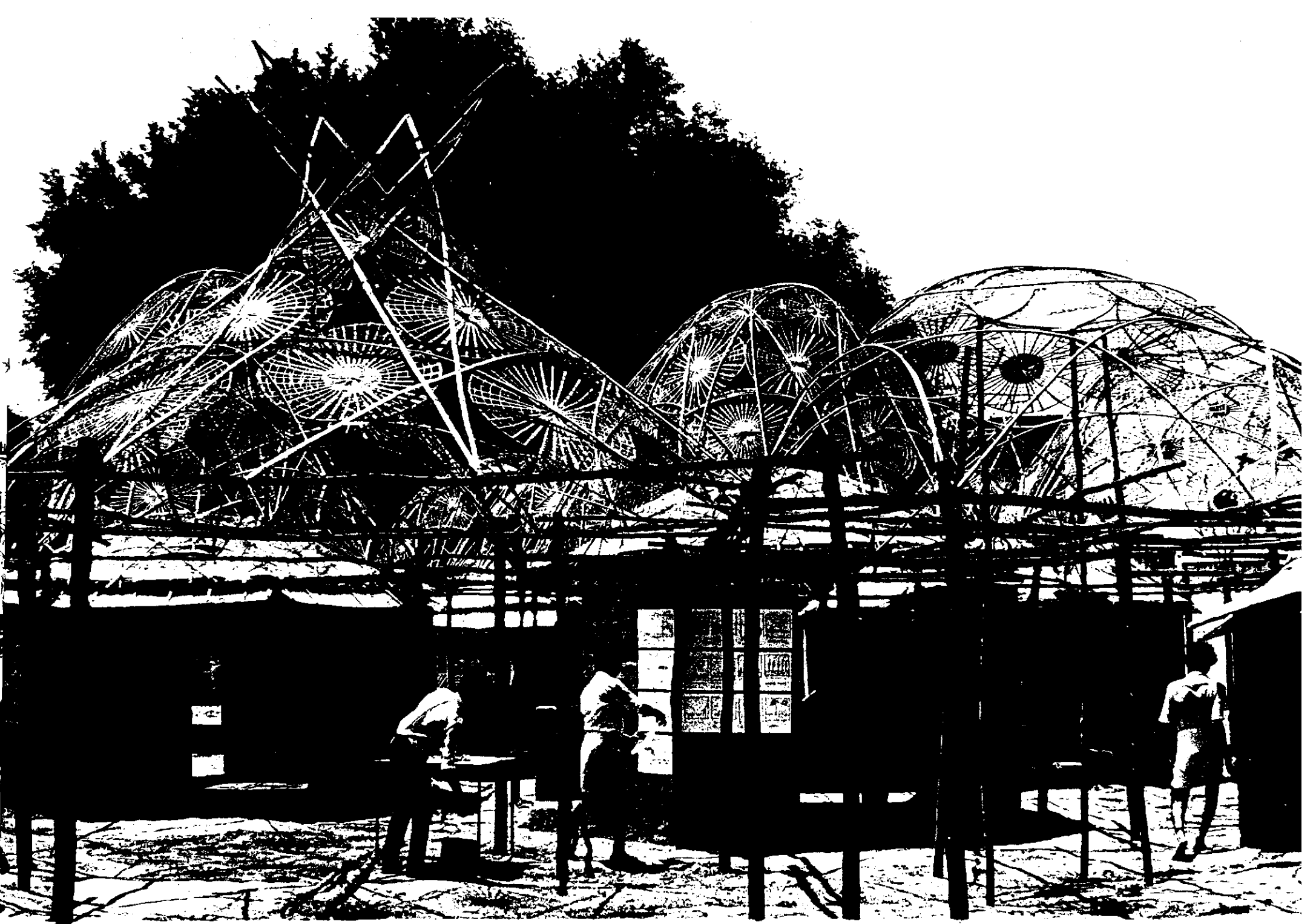


PLAN

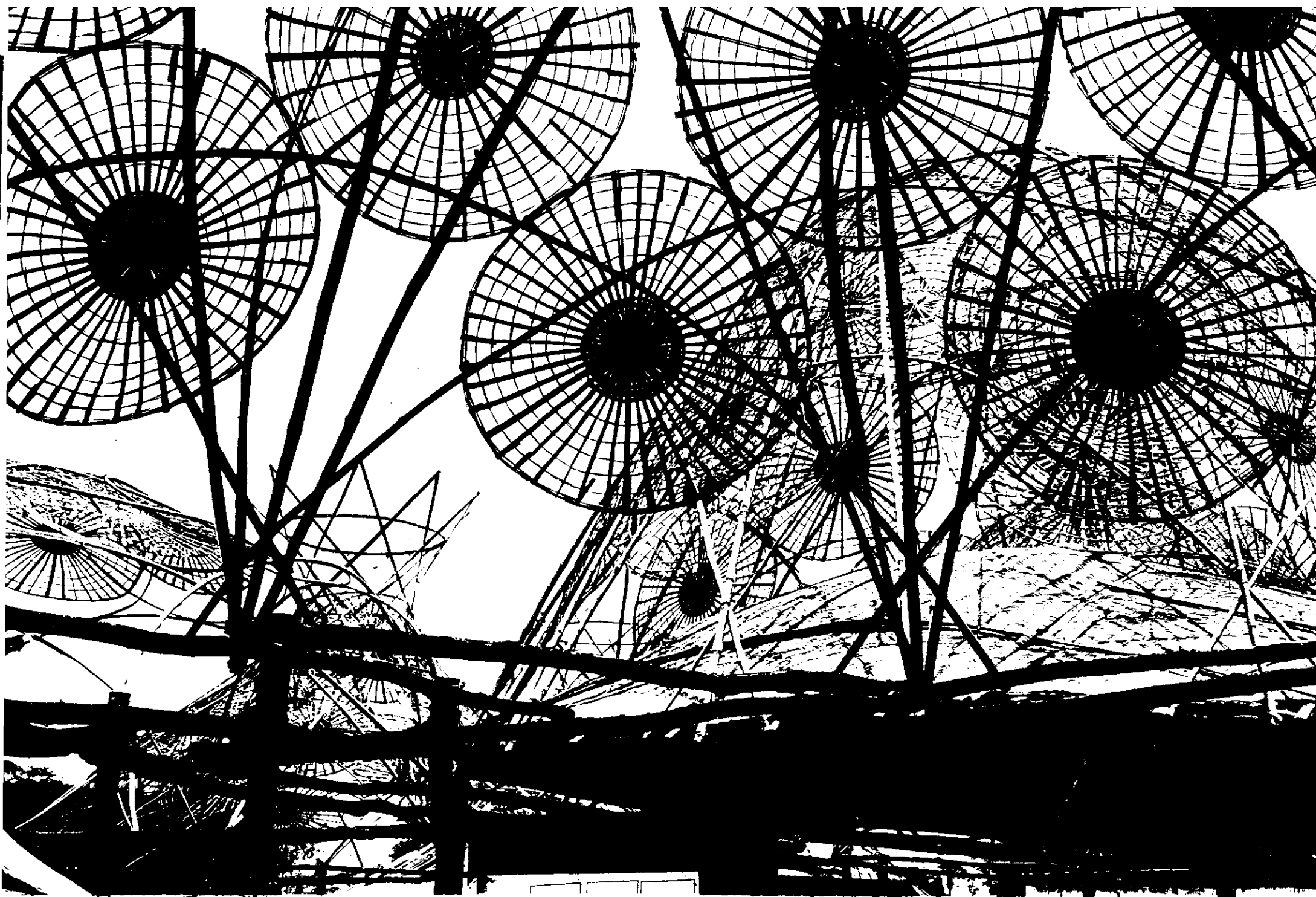














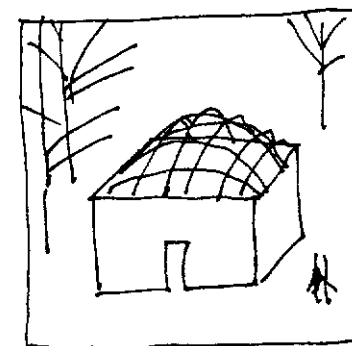
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

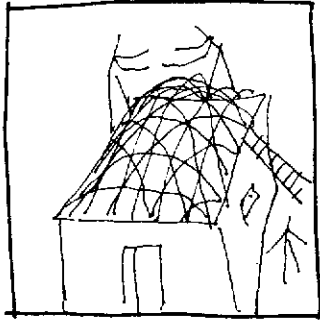
33, BD GARIBALDI, 75015 PARIS ☎ (331) 783-20-24

LATICE DOMES

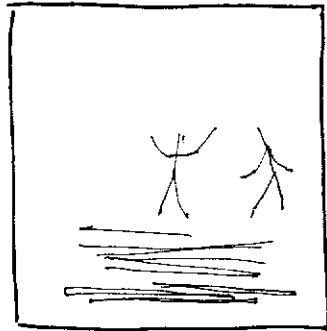




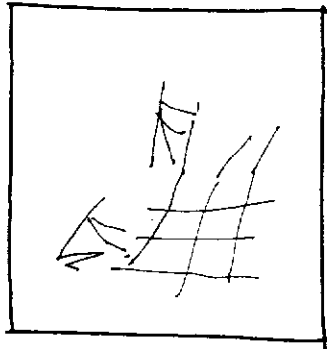
THERE IS AN EASY WAY
TO BUILD A LATTICE DOME;



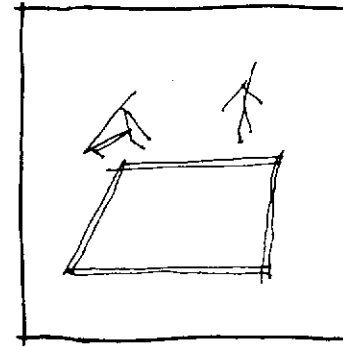
IT IS A VERY STRONG STRUCTURE



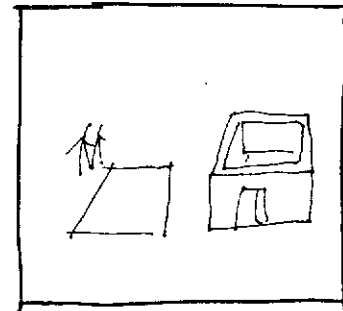
MAKING USE
OF LITTLE MATERIAL,



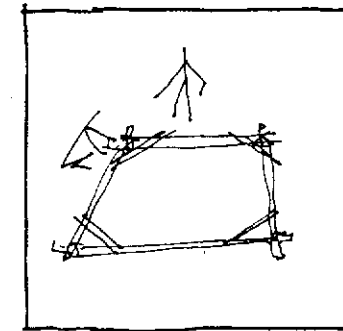
AND IT DOES NOT IMPLY
TOO MUCH SITE WORK.



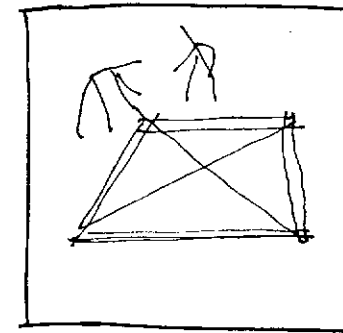
IN ORDER TO BUILD SUCH A DOME
YOU HAVE TO START
WITH A RIGID FRAME



WHICH FOLLOWS THE OUTLINE
OF THE HOUSE YOU WANT TO BUILD.

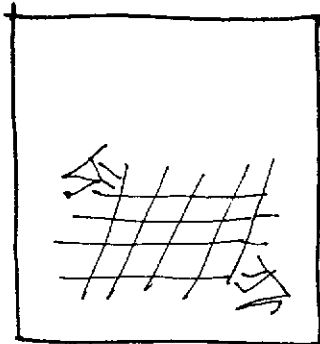


IN ORDER TO MAKE THAT FRAME
RIGID

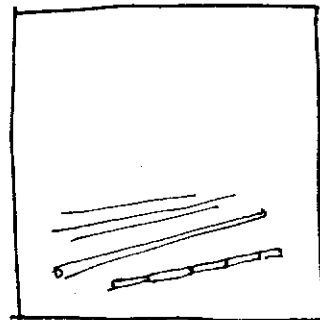


YOU HAVE TO STRENGTHEN
THE CORNERS OF IT,

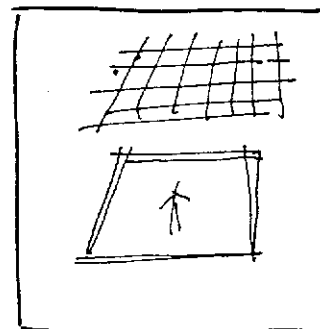
FOR EXAMPLE,
WITH DIAGONALS.



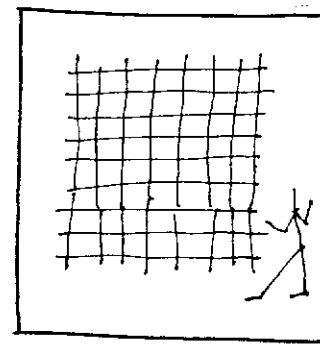
AFTER YOU BUILT THE FRAME,
THE NEXT STEP IS
TO COMPOSE, FLAT ON THE GROUND,
THE LATTICE.



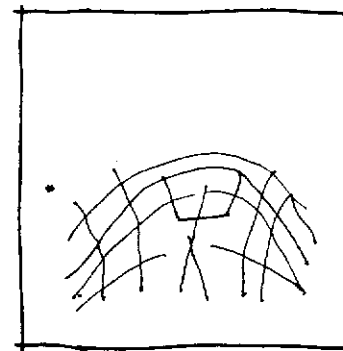
YOU CAN MAKE IT FROM WOOD,
FROM SPLIT BAMBOO
OR SIMILAR MATERIALS;



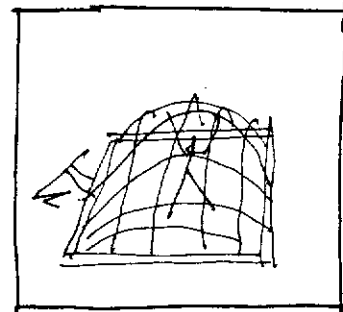
THAT LATTICE
HAS TO BE ABOUT $\frac{1}{3}$ LARGER
THAN THE FRAME.



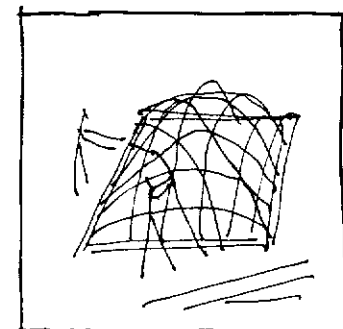
ITS MESHES
CAN BE ABOUT 1 TO $1\frac{1}{4}$ FEET WIDE.



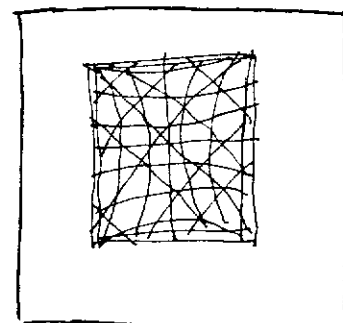
ONCE YOU FINISHED
COMPOSING THAT LATTICE
YOU SHOULD LIFT ITS CENTER



AND FIX ITS ENDS
(WHICH HANG FREELY)
TO THE RIGID FRAME.



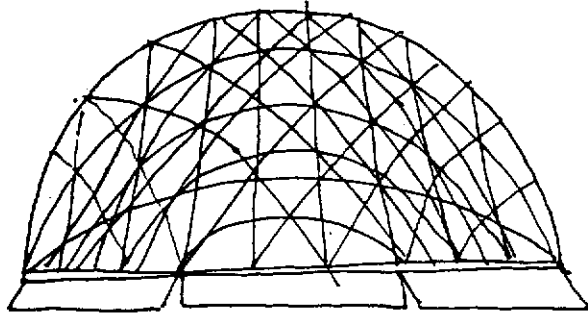
WHEN THE RESULTING LATTICE DOME
IS WELL FASTENED,
YOU SHOULD INTRODUCE DIAGONALS
INTO ITS MESHES;



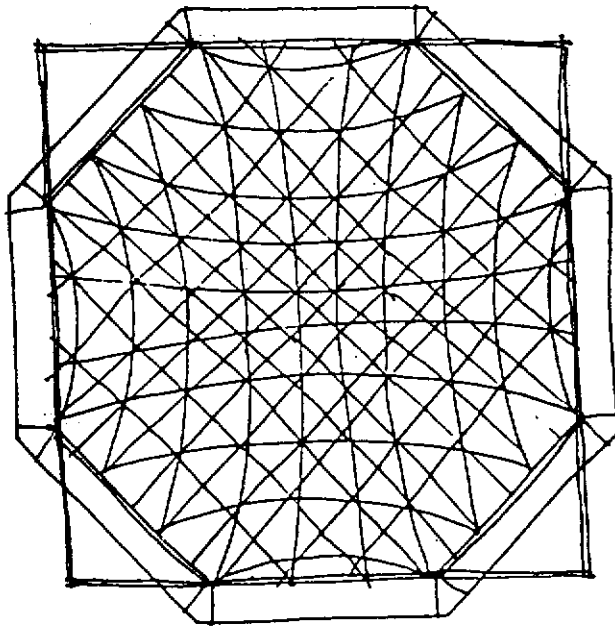
FIX THEM TO THE LATTICE,

THE RESULT WILL BE
A VERY SOLID DOME.

UPPER DOME

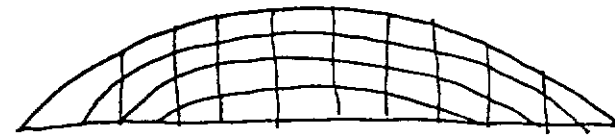


ELEVATION

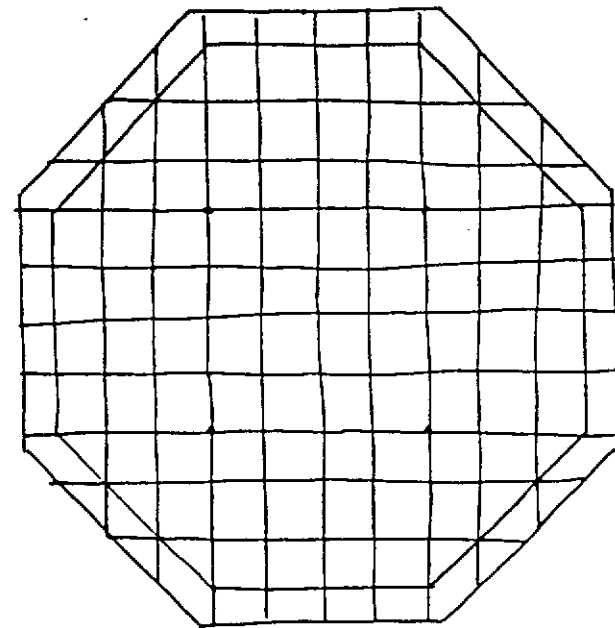


PLAN

LOWER DOME



ELEVATION



PLAN



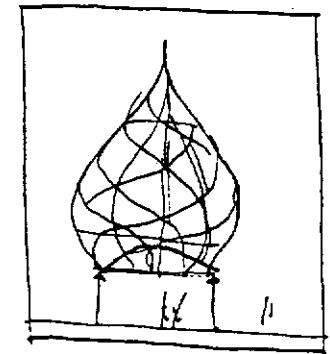
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



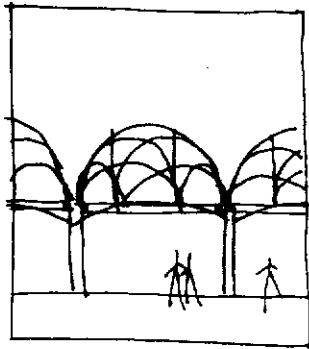
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BD GARIBOLDI, 75015 PARIS ☎ (331) 783-20-24

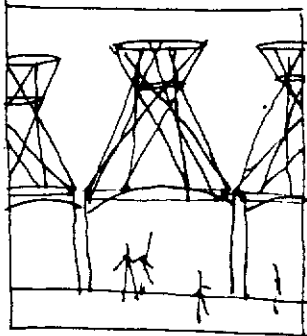
BULB-SHAPED DOMES



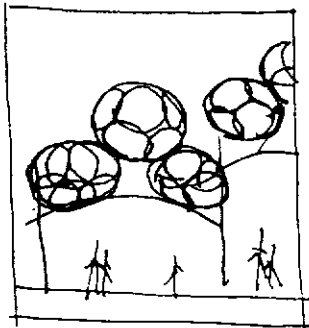
BASIC RESEARCH: EDA SCHAUR, IL, STUTTGART



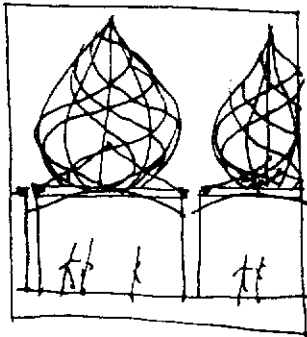
SUPPORT STRUCTURES
FOR DOMES WITH SUSPENDED ROOF-SKIN
CAN HAVE DIVERSE SHAPES.



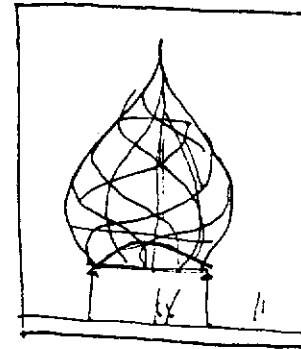
LIKE SIMPLE SPHERIC DOMES,
ROTATIONAL HYPERBOLOIDS,



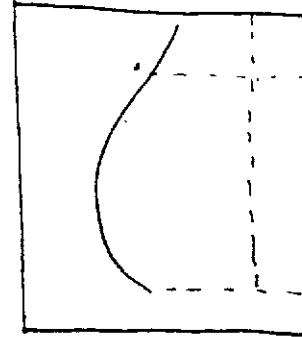
OR MORE COMPLEX SHAPES
LIKE "SPACE CHAINS"
(DOMES MADE WITH RINGS)



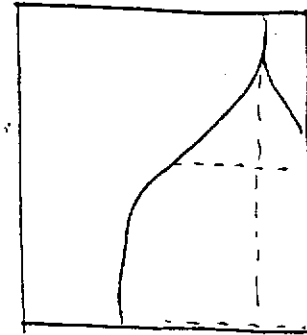
AND DOMES
OF MULTIPLE CURVATURE.



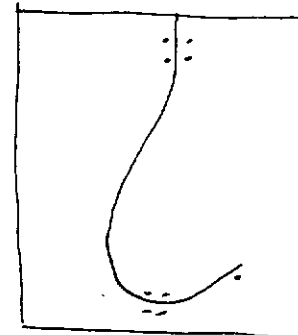
IN THIS LATTER GROUP
BULB-SHAPED DOMES
ARE AMONG THE MOST INTERESTING.



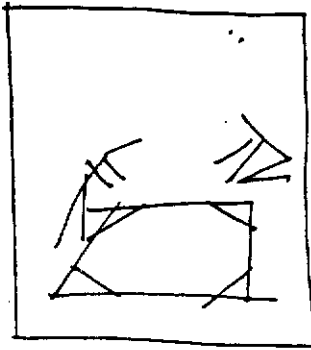
THE BULB SHAPE IS CHARACTERIZED
BY ONE CURVATURE (THE BULGE)
AT THE BOTTOM HALF



AND ANOTHER, OPPOSITE, ONE
(THE COUNTERBULGE)
IN THE UPPER HALF.



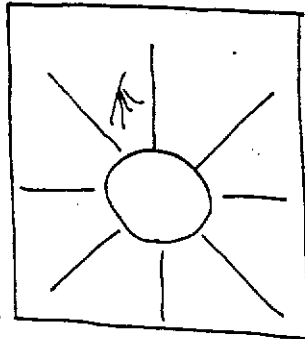
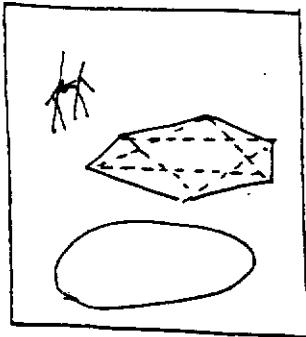
THAT KIND OF DOUBLE CURVATURE
COMES FROM BENDING A ROD
IN A PARTICULAR WAY.



IN ORDER TO BUILD
A BULB-SHAPED DOME
YOU HAVE TO START WITH A RIGID FRAME
SERVING AS THE BASE.

THIS STEP IS USUAL
WHEN BUILDING DOMES.

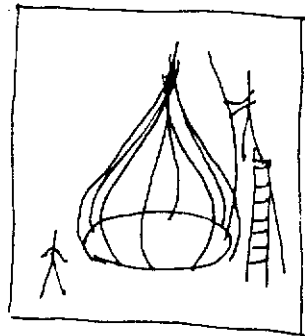
THAT FRAME CAN BE POLYGONAL
OR CIRCULAR.



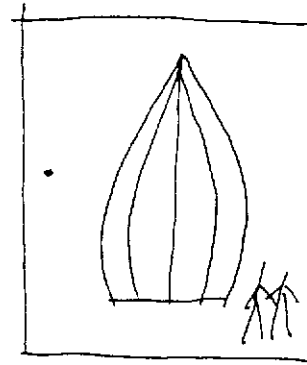
YOU SHOULD DISPOSE, ON THE GROUND,
AROUND THAT FRAME,
THE RODS WHICH WILL BE THE RIBS.

FIX THOSE RIBS TO THE FRAME,

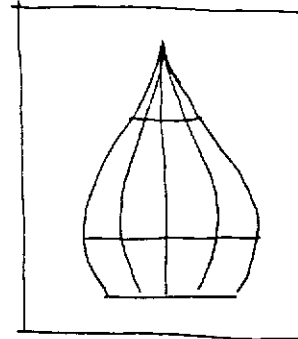
THEN BEND THEM UPWARDS
TILL THEIR ENDS MEET
IN THE AXIS OF THE FUTURE DOME.



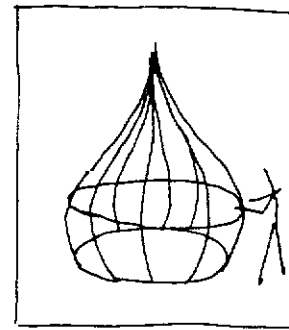
TIE THESE ENDS TOGETHER.



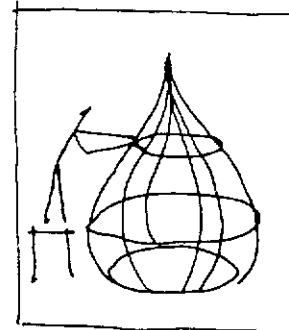
THE DOME, AT THAT STAGE,
WILL SEEM RATHER UNSHAPELY.



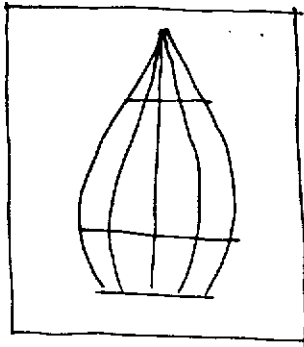
YOU SHOULD FIX TO THE RIBS
TWO BELTS,
WHICH WILL START TO DEFINE
THE FINAL SHAPE:



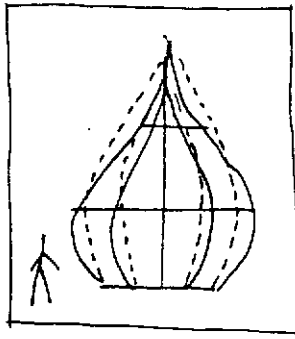
ONE BELT AT THE UPPER PART
OF THE BULGE,



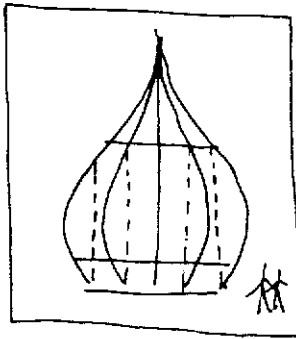
THE OTHER ONE
ABOVE THE COUNTERBULGE.



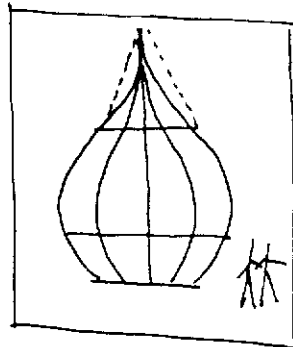
EVEN AT THAT STAGE
THE DOME WILL HAVE
ONLY AN APPROXIMATIVE BULB-SHAPE.



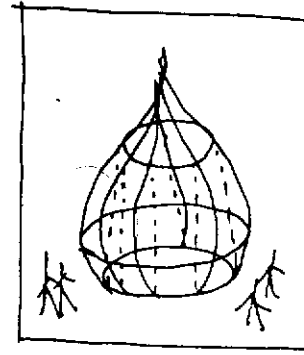
YOU HAVE TO FORCE THE RIBS
INTO THE RIGHT SHAPE
BY TENDING THEM WITH STRINGS.



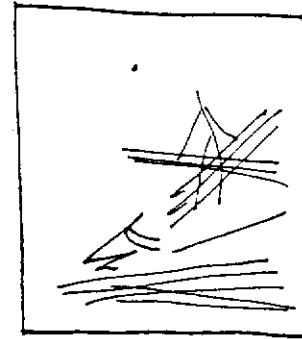
ONE STRING WILL DEFINE
THE BULGE,



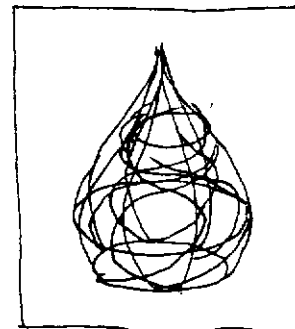
ANOTHER ONE THE COUNTERBULGE.



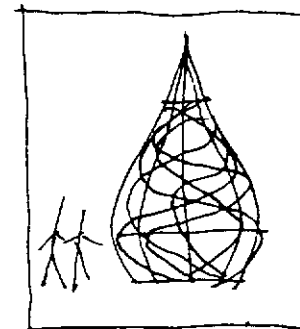
ONCE THE DOME
GOT THE REQUIRED SHAPE,
THANKS THE STRINGS,



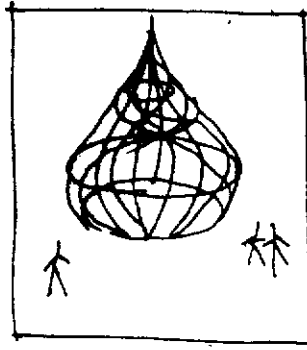
YOU SHOULD PREPARE
LONG THIN BAMBOO STRIPS,
TWO FOR EACH RIB.



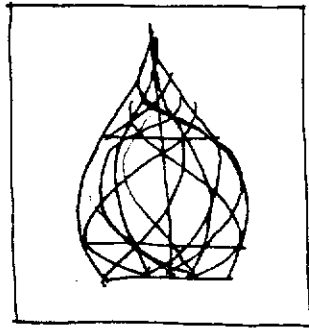
DISPOSE THOSE STRIPS IN SPIRALS
AROUND THE ONION SHAPE
AND FASTEN THEM TO THE RIBS,



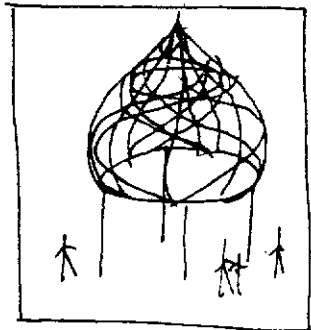
FIRST THE SPIRALS ONE WAY,
THEN THE COUNTERSPIRALS
THE OPPOSITE WAY.



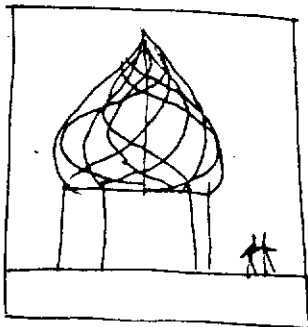
WITH THOSE SPIRALS FASTENED
THE BULB-SHAPED DOME
BECOMES RIGID AND READY.



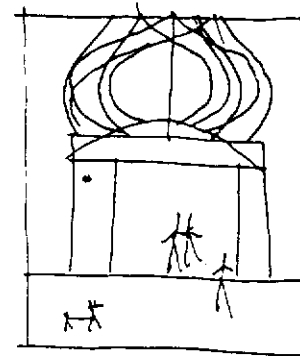
YOU DONT NEED THE STRINGS ANYMORE
AND CAN TAKE THEM AWAY.



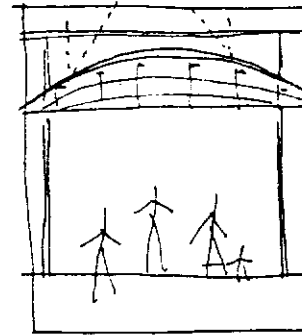
THE DOME WILL KEEP ITS WANTED SHAPE



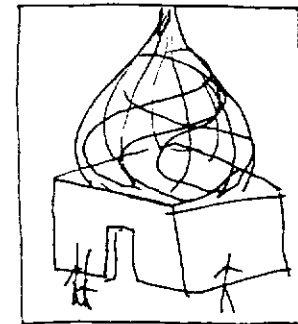
AND BE VERY SOLID.



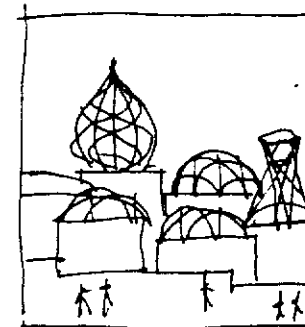
THAT DOME CAN SUPPORT EASILY
THE ROOF-SKIN
YOU WILL SUSPEND ON IT,



PROCEEDING IN THE SAME MANNER
AS WITH OTHER SIMILAR DOMES.



YOUR ROOF WILL LOOK BEAUTIFUL
WITH SUCH A DOME,



AND YOUR HOUSE
WILL BE EASY TO DISTINGUISH

AMONG THE OTHER HOUSES.

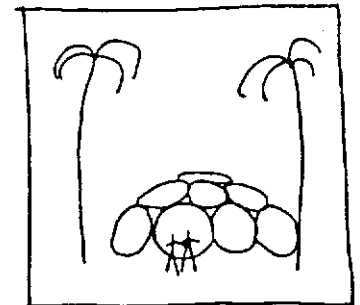


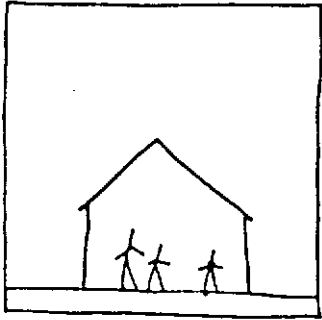
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



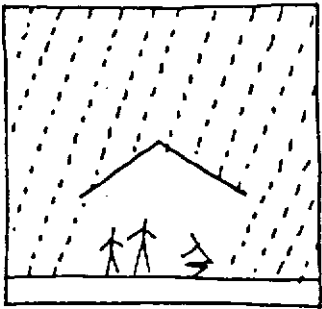
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

RINGS INTO ROOFS

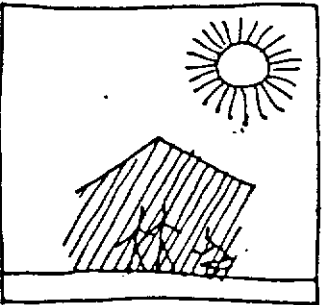




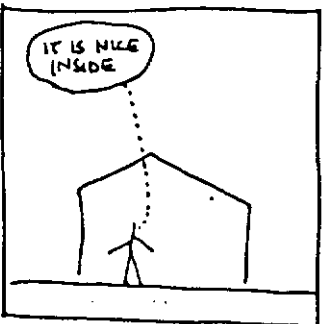
THE ROOF
IS THE MOST IMPORTANT PART
OF THE HOUSE.



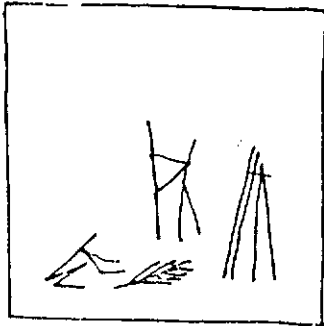
IT IS THE ROOF
WHICH SHELTERS US OF THE RAIN



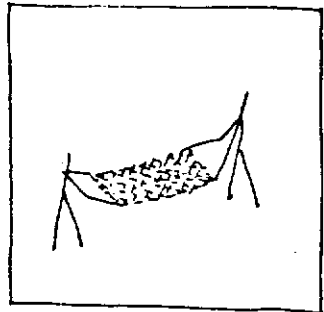
AND IT IS THE ROOF
WHAT PROTECTS US FROM THE SUN.



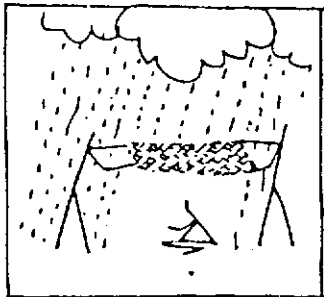
THE ROOF KEEPS US DRY AND COOL.



IT IS IMPORTANT
TO KNOW HOW TO CONSTRUCT A ROOF.

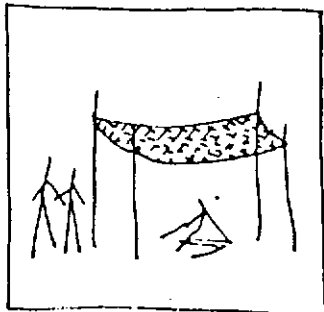


A ROOF CONSISTS
OF TWO MAIN PARTS:



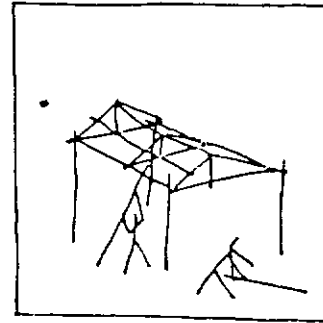
A "SKIN",

WHICH DOES NOT LET
THE RAIN OR THE SUN IN,

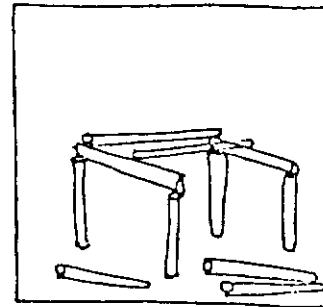


AND A "SKELETON",

WHICH IS STRONG ENOUGH
TO KEEP THE ROOF UP.

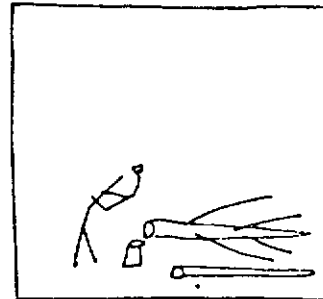


LET US LOOK FIRST
AT THE SKELETON:

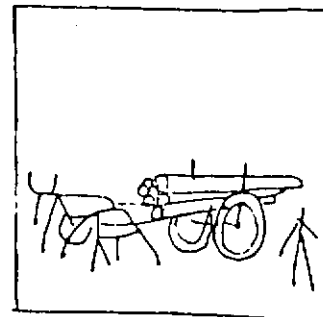


YOU START WITH THE SKELETON
WHEN BUILDING A ROOF.

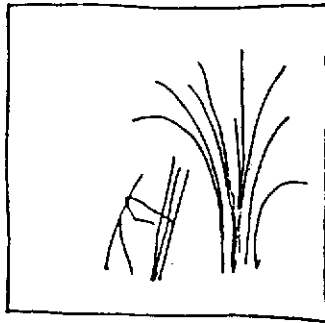
THE SKELETON
CAN BE MADE OUT OF HEAVY TIMBER:



THIS IS EXPENSIVE

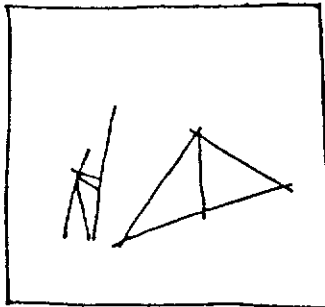


AND DIFFICULT TO BUILD.



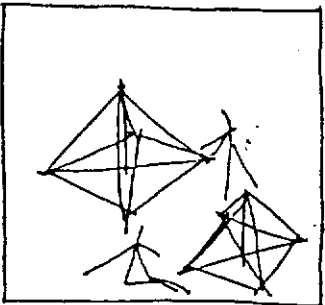
YOU CAN USE
LIGHTWEIGHT BAMBOO, AS WELL,

BUT BAMBOO IS LESS STRONG
THAN HEAVY TIMBER.

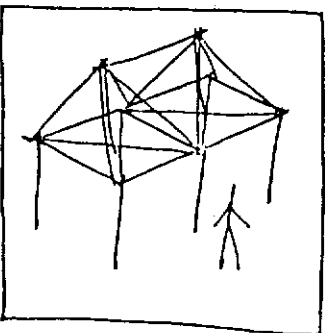


TRUSSES OF BAMBOO
HAVE TO HAVE CERTAIN FORM

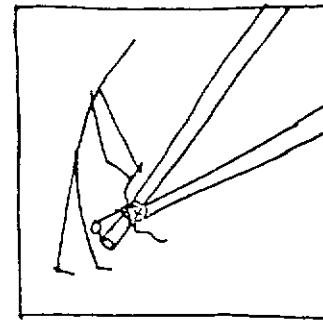
IN ORDER TO BE STRONG.



TRIANGLES MADE OF BAMBOO RODS,
OR FIGURES COMPOSED
OF SEVERAL TRIANGLES

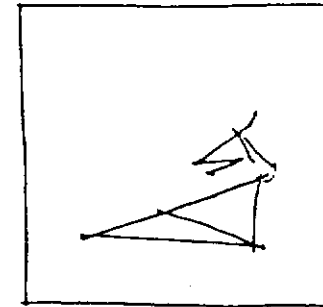


CAN BE MUCH STRONGER
THAN A SIMPLE TRUSS OF TIMBER.

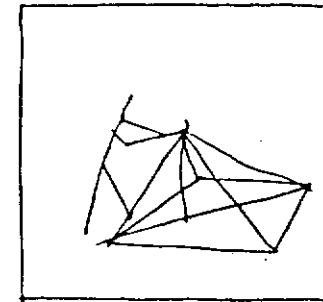


YOU CAN BUILD SUCH TRIANGULAR FORMS

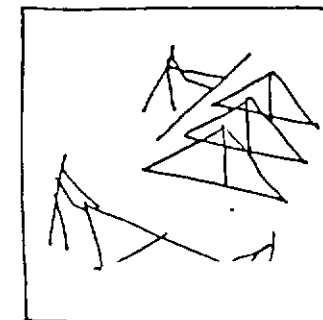
BY FIXING SEVERAL BAMBOO RODS
BY STRINGS.



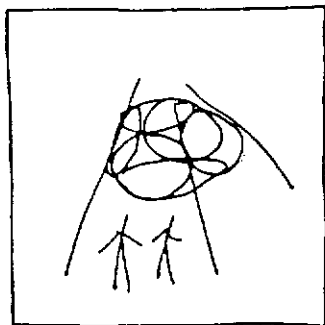
YOU CAN FIX FIGURES
WHICH ARE "PLANE"
(SO YOU CAN LAY THEM FLAT
ON THE GROUND
WHEN WORKING ON THEM).



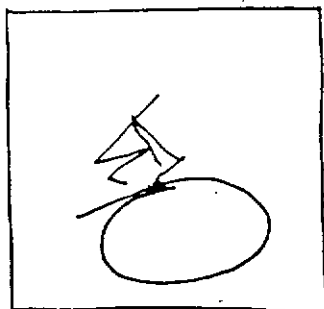
OTHER FIGURES ARE IN "SPACE":
YOU CAN NEVER FLATTEN THEM OUT.



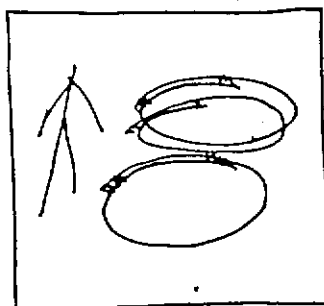
SUCH FIGURES ARE THE ELEMENTS
FOR SKELETONS OF ROOFS.



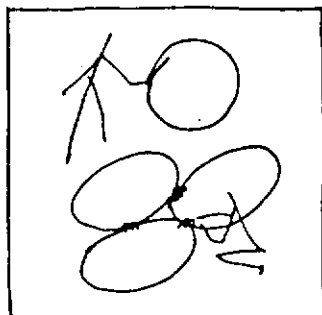
YOU CAN COMPOSE SKELETONS FOR ROOFS WITH BAMBOO RINGS AS WELL.



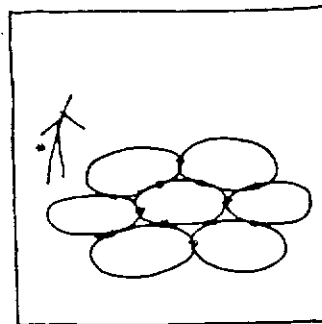
YOU MAKE SUCH RINGS BY BENDING BAMBOO IN A CERCLE AND FIXING THE ENDS WITH A STRING,



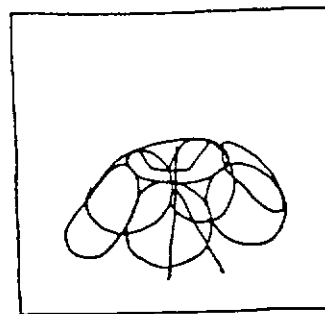
AS BASKETMAKERS DO.



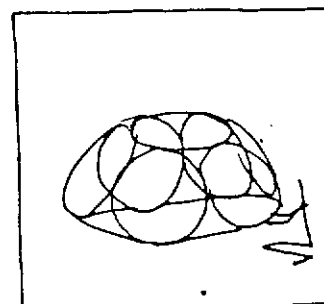
YOU CAN FASTEN, STILL WITH STRINGS, SEVERAL SUCH RINGS TOGETHER.



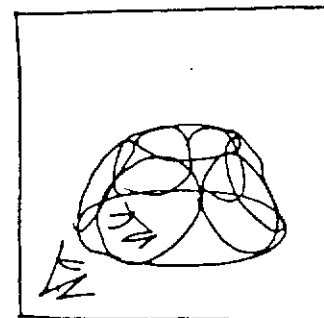
YOU CAN STRING TOGETHER SEVERAL BAMBOO RINGS FLAT ON THE FLOOR



INTO A PARTICULAR PATTERN. THEN YOU LIFT UP SLOWLY THE CENTRAL RING OF THIS NET

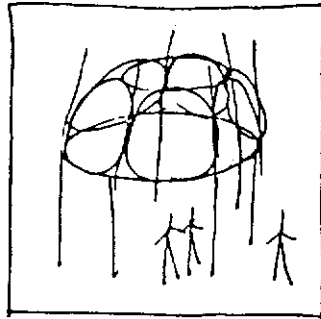


AND TEND WITH ANOTHER STRING THE EXTERNAL PART OF THE EXTERNAL RINGS.

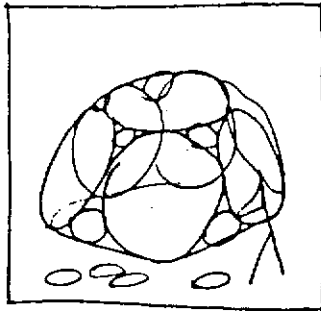


WHEN YOU HAVE FINISHED TENDING AND TO FIXING THE STRING

THE DOME YOU HAVE BUILT WILL REMAIN STANDING.

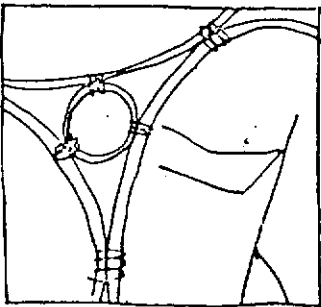


IF YOU WANT THE DOME
YOU HAVE BUILT

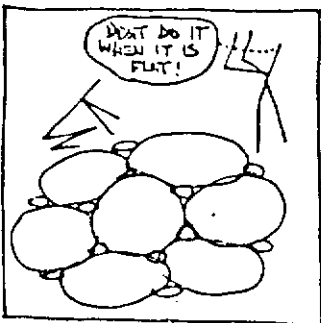


TO BE PARTICULARLY STRONG,

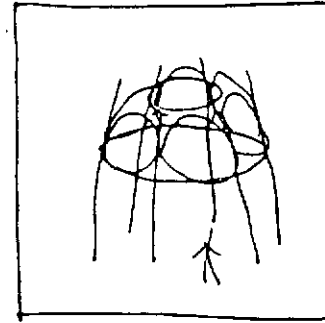
YOU SHOULD MAKE A FEW
SMALLER RINGS



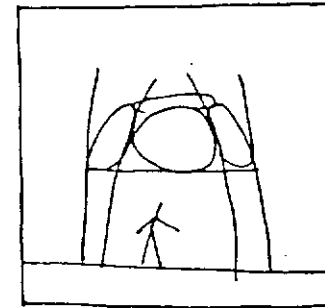
AND FIT THEM IN THE VOIDS
AMONG THE LARGE RINGS,



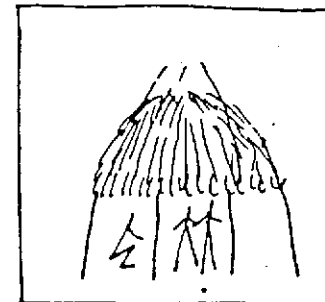
ONCE THE DOME IS IN POSITION.
(IF YOU DO IT EARLIER,
YOU CANNOT GIVE THE DOME ITS SHAPE).



IT IS EASY TO BUILD
SUCH A DOME-SKELETON
FOR YOUR ROOF;

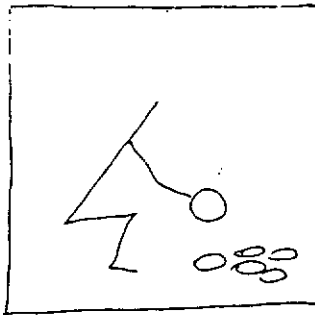


IT CAN BE ABOUT 4-5 METERS LARGE
(WHEN RINGS ARE ABOUT 2 METERS
IN DIAMETER).

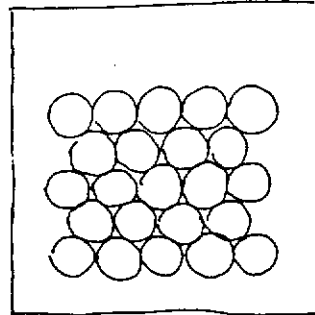


YOU COVER THEN THE SKELETON
WITH MATS,
LEAFS OR STRAW

IN THE WAY
AS IS USUAL IN YOUR REGION.

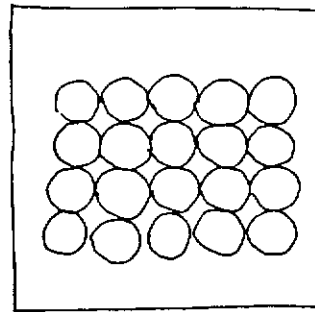


ANOTHER TECHNIQUE COULD BE
TO COMPOSE A CONTINUOUS NET



OUT OF RINGS
NOT LARGER THAN ONE FOOT.

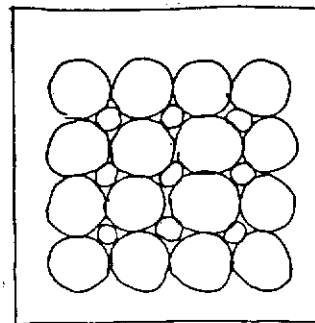
THIS NETWORK CAN BE MADE
IN SEVERAL WAYS:



EACH RING CAN TOUCH
6 OTHER RINGS,

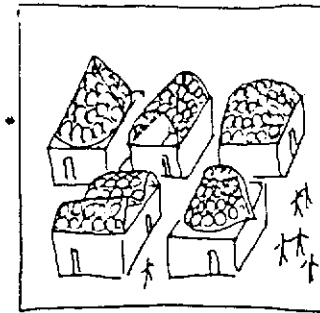
OR IT CAN BE NEIGHBOUR
TO 4 OTHER ONES,

(EXCEPT THOSE AT THE EDGE OF THE NET,
OBTAININGLY).

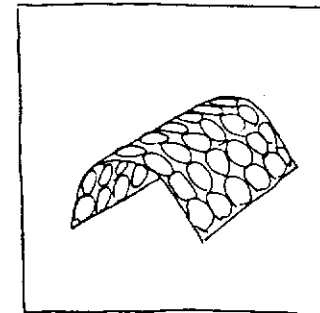


THE RINGS CAN BE
ALL THE SAME SIZE,

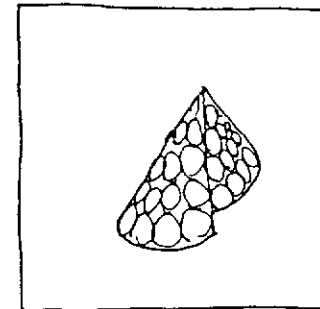
OR
DIFFERENT SIZES.



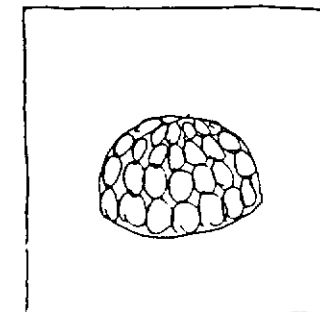
YOU CAN BEND
OR FOLD
THIS NETWORK INTO MANY SHAPES:



YOU CAN MAKE A VAULT,

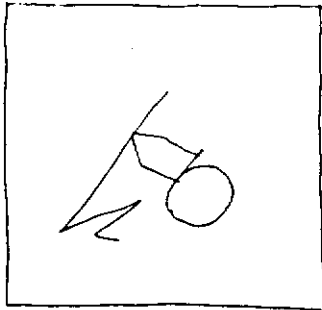


OR A SORT OF A CONE,

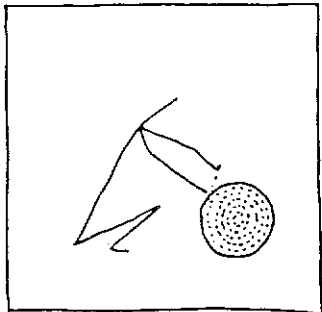


OR EVEN A DOME.

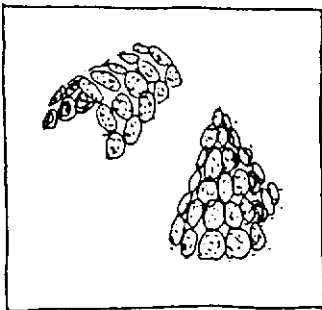
ALL THESE STRUCTURES WILL STAND.



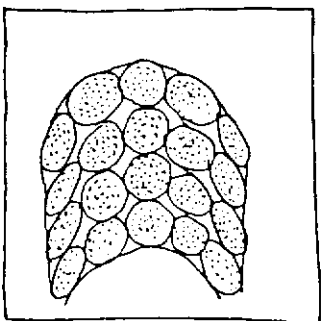
IT COULD BE ADVANTAGEOUS
IF, INSTEAD USING A SIMPLE RING



YOU WOULD USE FLAT ROUND BASKETS
OF WHICH THE BAMBOO RING
COULD REPRESENT THE RIM.



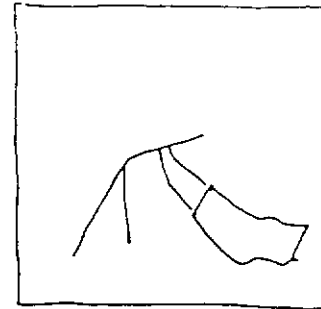
THUS, YOUR VAULT, OR CONE, OR DOME
OR ANY OTHER SHAPE
YOU MIGHT CHOOSE



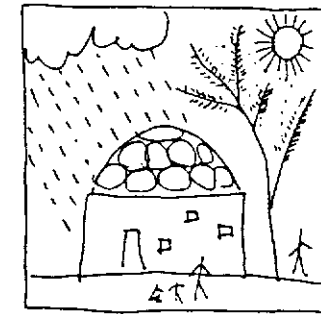
WILL BECOME MORE STURDY

AND WILL FORM A SURFACE
WITH INTERSTICES

INSTEAD SIMPLY FORMING A NET.



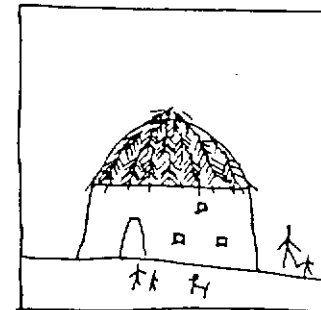
IF YOU CAN OBTAIN
SOFT PLASTIC SHEETS
(AS USED FOR WRAPPING OF MANY PRODUCTS)



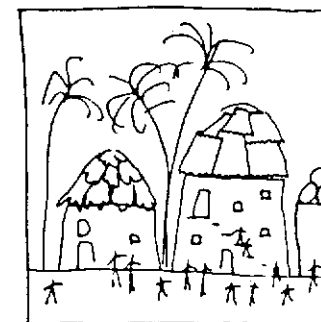
AND COVER YOUR ROOF MADE OF BASKETS
WITH IT.

YOUR ROOF WILL BECOME WATERIGHT,
AND THE PLASTIC SHEET
WILL LET THROUGH THE LIGHT
AT THE INTERSTICES BETWEEN BASKETS.

IF YOU WANT TO PRESERVE THE PLASTIC
YOU SHOULD PROTECT IT
AGAINST HARD SUN, BY KEEPING IT IN SHADE.



YOU CAN COVER A ROOF MADE OF BAMBOO RINGS
BY ANY LIGHTWEIGHT MATERIAL OF ROOFING
YOU ARE USED TO USE,



THE RINGS AND THE FLAT BASKETS
WILL SERVE AS A SOLID SUPPORT
FOR THE ROOFING MATERIAL

YOU MIGHT CHOOSE.



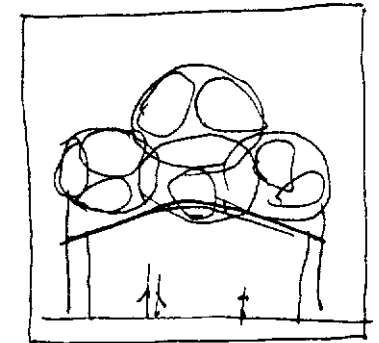
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



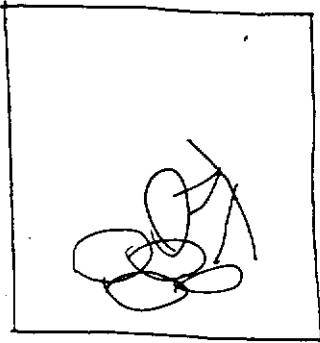
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BD GARIBOLDI, 75015 PARIS ☎ (331) 783-20-24

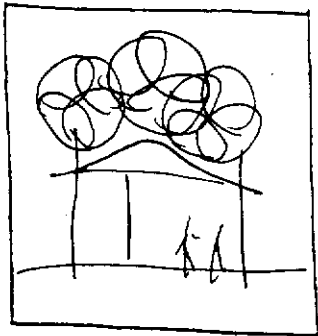
STRUCTURES
MADE WITH RING-BAUS



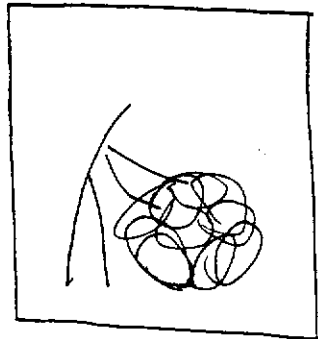
BASIC RESEARCH: YONA FRIEDMAN, CCSR, PARIS



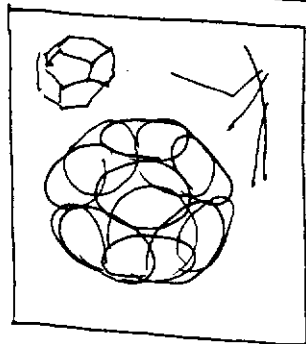
ONE OF THE SIMPLEST STRUCTURE.
MADE WITH RINGS



IN ORDER TO SUPPORT
A SUSPENDED ROOF-SKIN

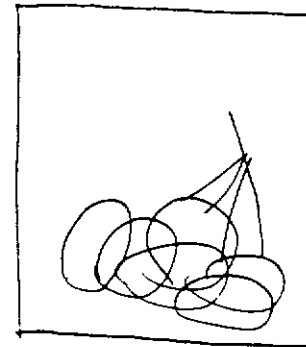


IS MADE
WITH BALL-LIKE CONFIGURATIONS

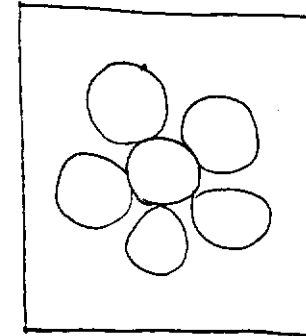


CONTAINING 12 RINGS.

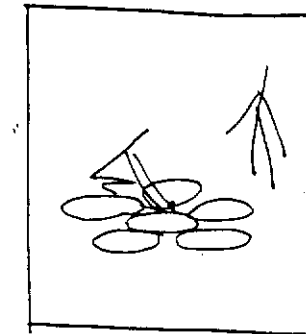
THESE CONFIGURATIONS
ARE CALLED "DODECAHEDRA".



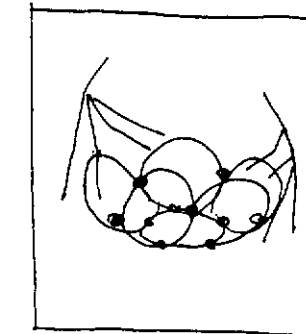
TO BUILD A DODECAHEDRON
YOU START
WITH DISPOSING 6 RINGS ON THE FLOOR,



IN A FLOWER-LIKE ARRANGEMENT:
ONE RING IN THE CENTER
SURROUNDED BY 5 OTHER RINGS.

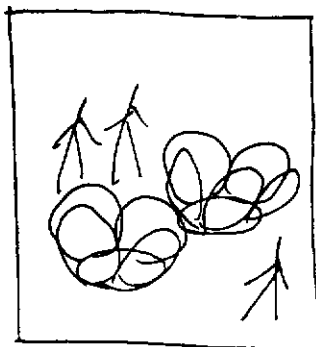


YOU TIE TIGHTLY THE "PETAL" RINGS
TO THE CENTRAL ONE,



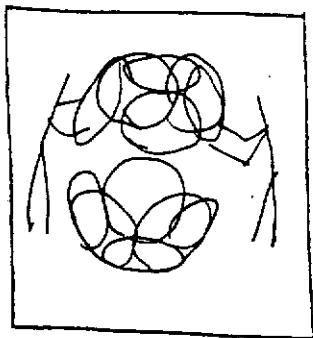
THEN YOU LIFT THE "PETALS"
TILL THEY FORM A CUP-LIKE FIGURE.

THEN TIE THEM IN THAT POSITION.

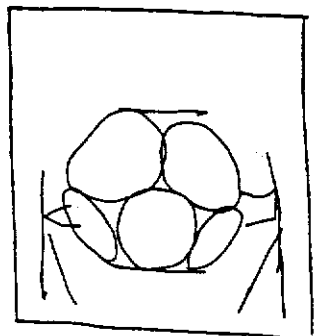


IN ORDER TO BUILD A DODECAHEDRON
YOU NEED 2 SUCH CUP-LIKE FIGURES.

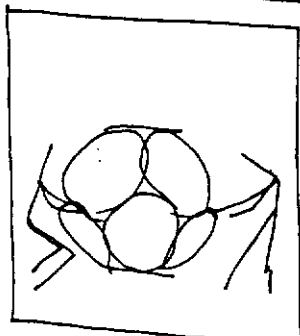
YOU SHOULD LEAVE THE FIRST ONE
ON THE GROUND, IN A CUP-LIKE POSITION.



THEN YOU LIFT THE SECOND CUP
AND POSE IT, UPSIDE DOWN
ONTO THE FIRST CUP.

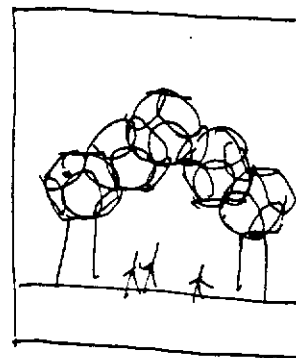


IT IS IMPORTANT,
THAT EACH PETAL OF THE UPPER CUP
SHOULD BE FITTED INTO THE HOLLOW
BETWEEN TWO PETALS OF THE LOWER CUP.

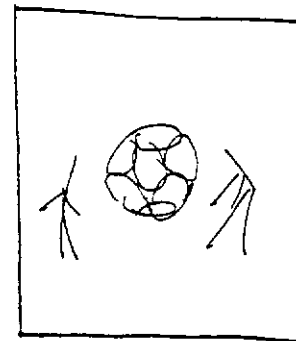


YOU SHOULD THEN TIE TOGETHER
BOTH CUPS, BY THEIR PETALS,

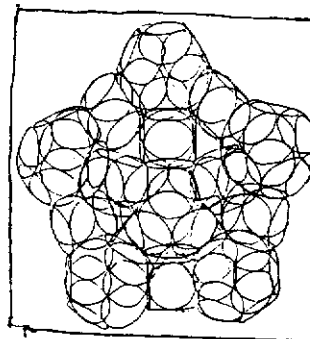
THE RESULTING BALL
WITH 12 FACES
WILL BE A DODECAHEDRON.



YOU CAN BUILD DOME-LIKE STRUCTURES
WITH THOSE BALLS.



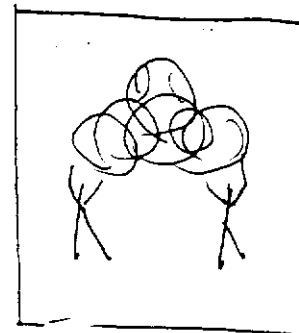
FOR EXAMPLE,
YOU CAN FIT TOGETHER 6 SUCH BALLS,



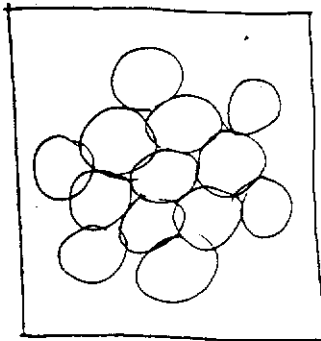
ONE IN THE CENTER

AND THE 5 OTHER BALLS
FORMING A CROWN

FASTENED TO THE 5 RINGS
OF THE BELT MAKING UP THE LOWER CUP
OF THE CENTRAL BALL.

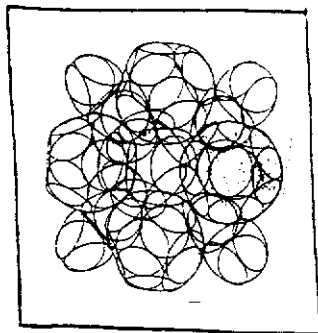


THAT STRUCTURE
WILL BE FAIRLY SOLID.

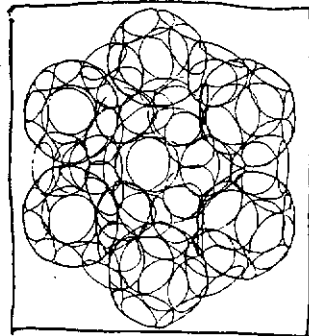


YOU CAN BUILD, IN A SIMILAR WAY,
CROWNS MADE OF ANY NUMBER
OF 12-FACED BALLS,

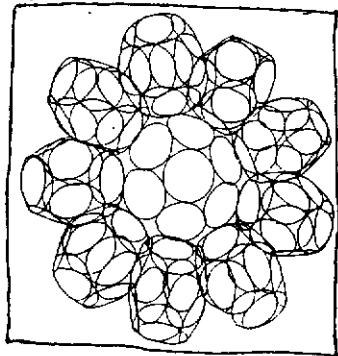
BY TYING THOSE BALLS TOGETHER
TO FORM A RING:



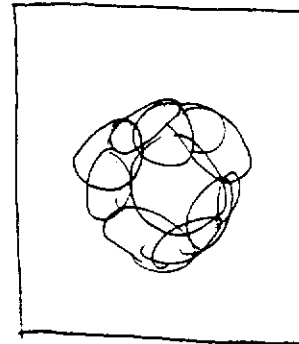
4 BALLS,



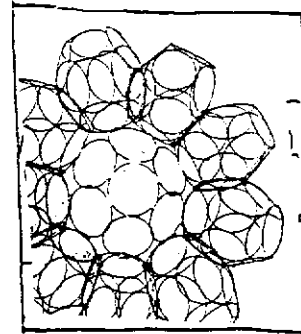
6 BALLS,



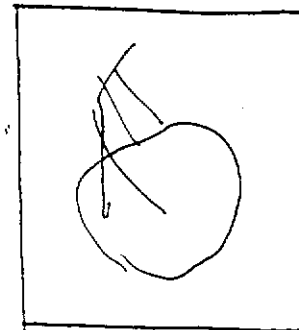
9 BALLS, OR MORE.



THE RING-BALLS,
ASSEMBLED INTO SUCH CONFIGURATIONS,
WILL GET DEFORMED..

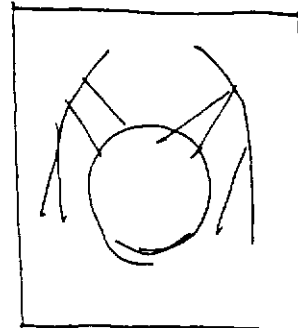


THAT DEFORMATION
WILL TEND THE STRUCTURE
LIKE A SPRING.

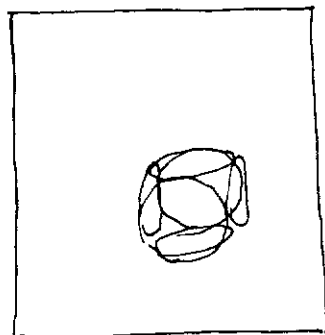


FOR THAT EFFECT
IT IS NECESSARY TO CARE
THAT THE CONSTITUTING RINGS

SHOULD NOT BE TOO WEAK
(ELSE THEY BURST)

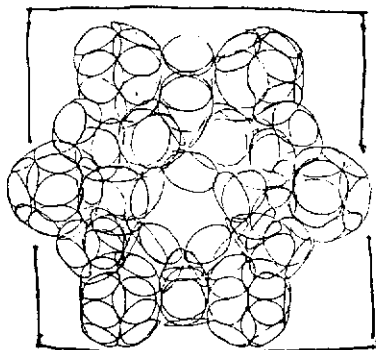


NOR TOO STRONG
(ELSE THEY DON'T GET DEFORMED).

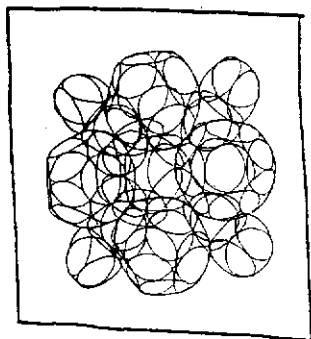


YOU CAN TRY MANY COMBINATIONS
TO BUILD SUCH STRUCTURES.

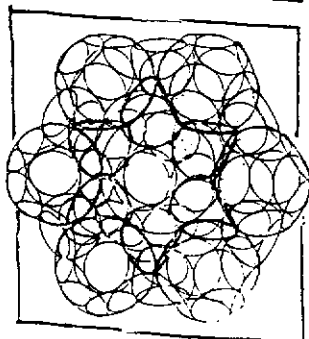
FOR EXAMPLE,
BY INSERTING CUBES
(MADE WITH 6 RINGS)



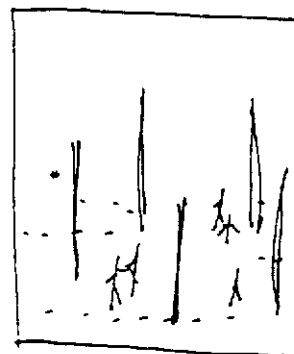
BETWEEN ANY 2 DODECAHEDRA.



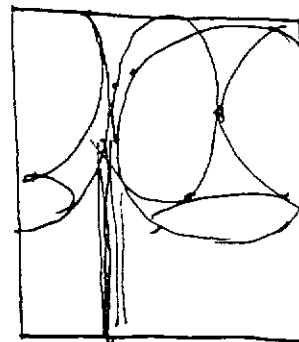
YOU CAN ADD TETRAHEDRA TOO
(MADE WITH 4 RINGS).



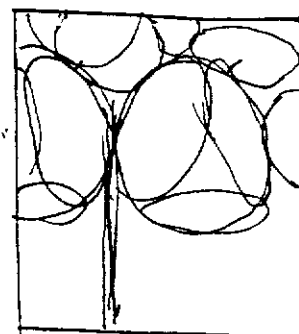
THESE COMBINATIONS
WILL BE PARTICULARLY STRONG.



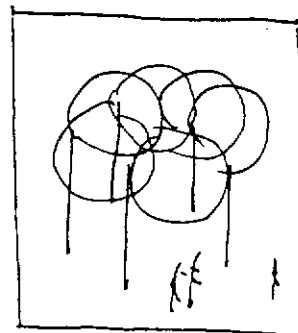
THESE DOMES BUILT WITH RINGS,
WILL BE SUPPORTED
BY WOODEN POSTS (FOR EXAMPLE).



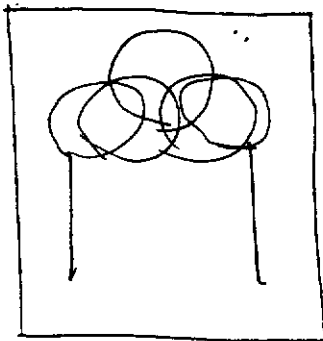
IT IS IMPORTANT THAT THE DOMES
SHOULD BE FASTENED TO THE POSTS
IN SPOTS



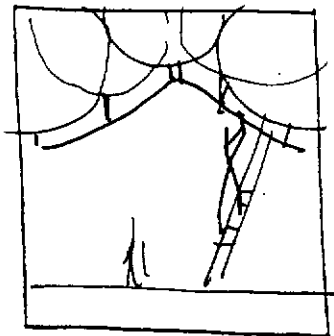
WHERE SEVERAL RINGS MEET
AND, IF POSSIBLE,
WHERE THEIR TANGENT
IS NEAR TO VERTICAL.



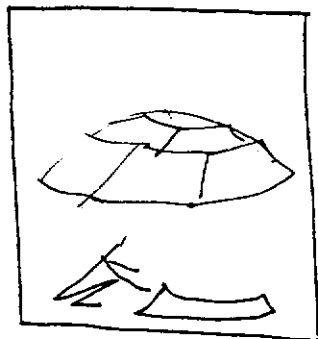
THUS, ACCORDING THE KIND OF THE DOME
THERE WILL BE
3, 4 OR 5. POSTS.



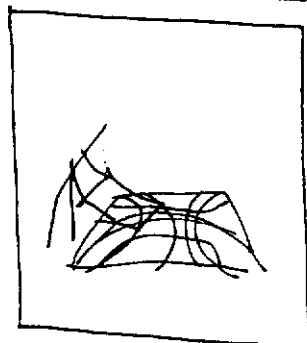
ONCE THE RING DOME
IS FIXED ONTO THE POSTS,



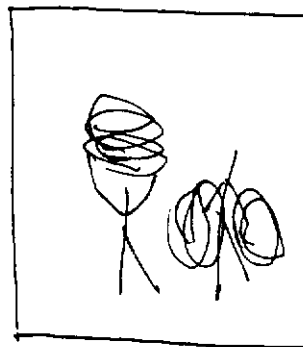
YOU CAN SUSPEND THE ROOF-SKIN
ON THE STRUCTURE,



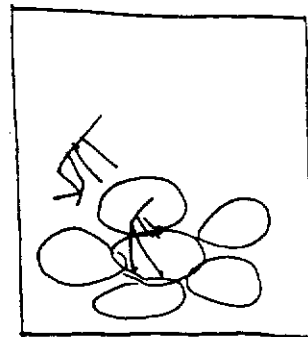
A SKIN MADE, FOR EXAMPLE,
WITH ALUMINIUM FOIL
GLUED ONTO BAMBOO MATS,



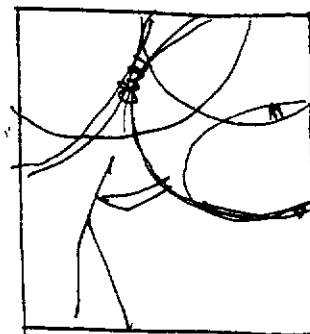
WHICH ARE FASTENED
ON A FLEXIBLE BAMBOO GRID,
WHICH HANGS ON ROPES
FASTENED TO THE RING-DOME.



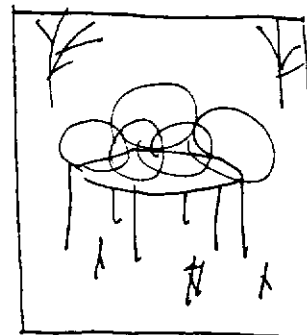
SUCH A STRUCTURE IS LIGHTWEIGHT
AND DOES NOT NEED
MUCH MATERIAL.



IT IS EASY AND FAST
TO BUILD IT,

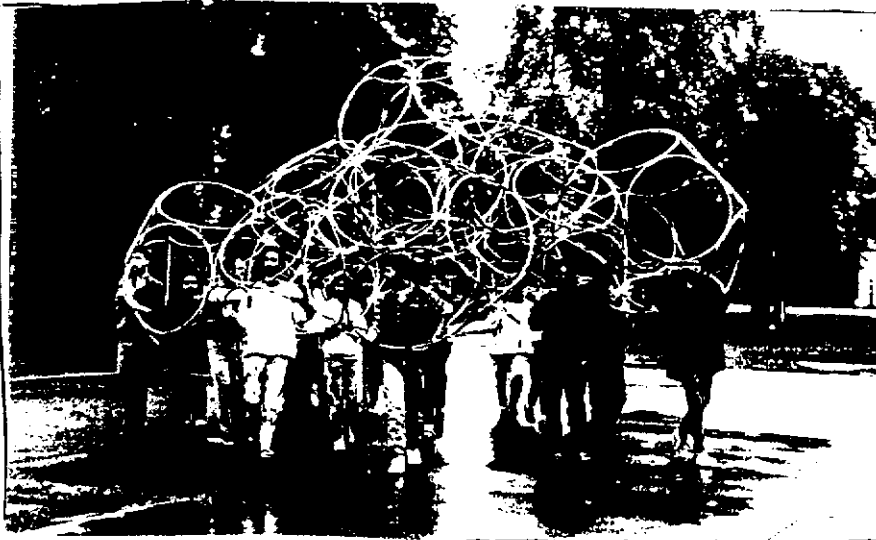
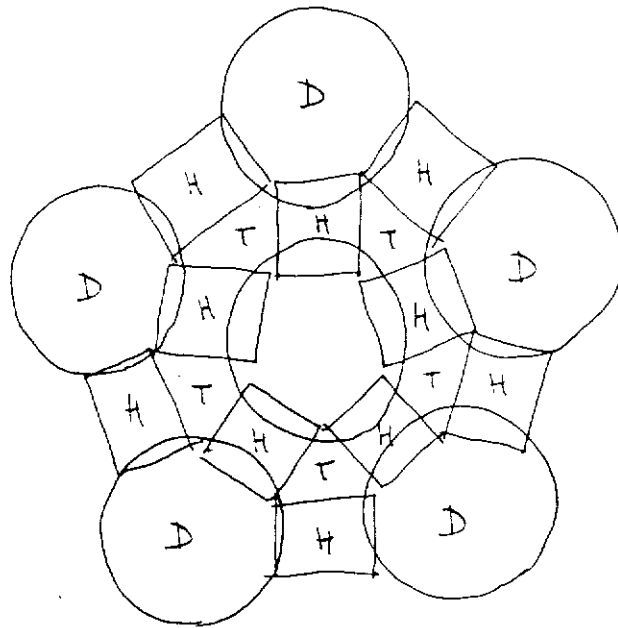


AND, IF THE LINKS ARE
SOLIDLY TIED,

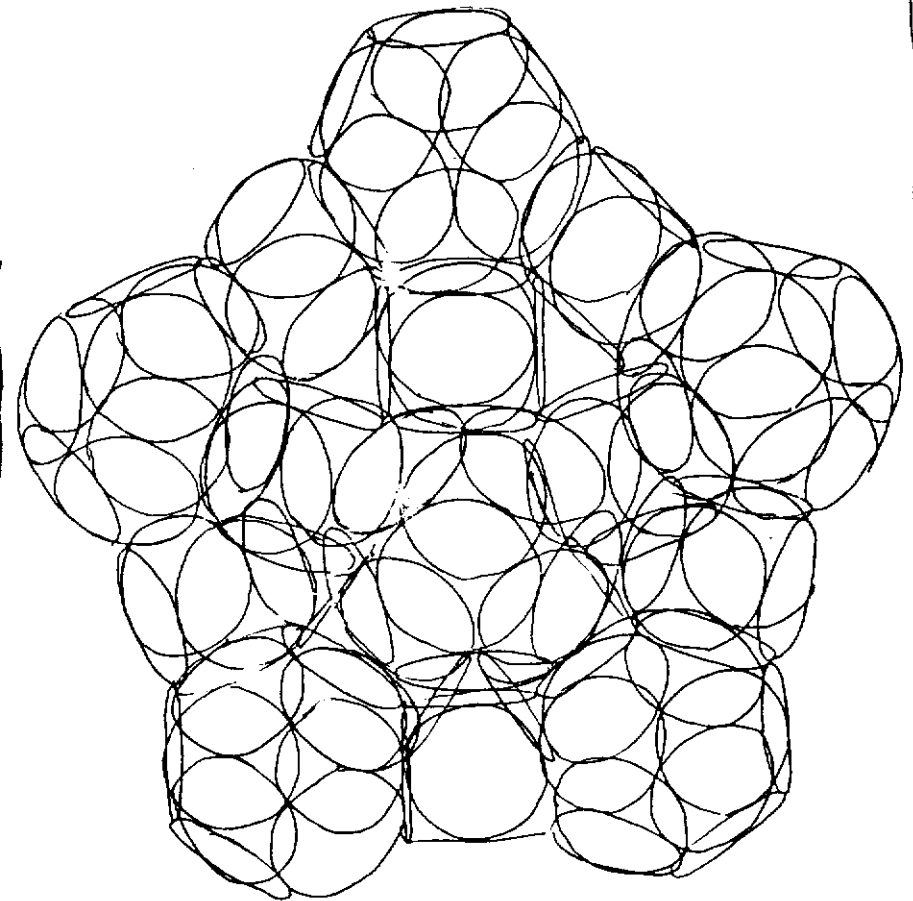


THE STRUCTURE CAN BE
PARTICULARLY STRONG.

SCHEMA

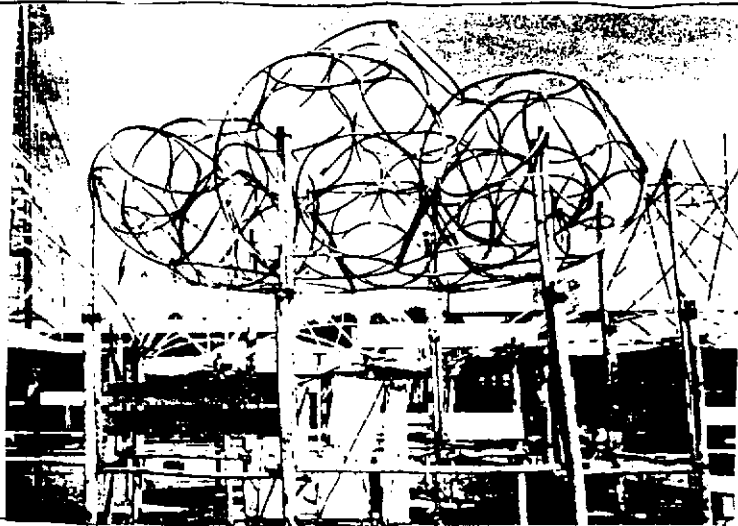
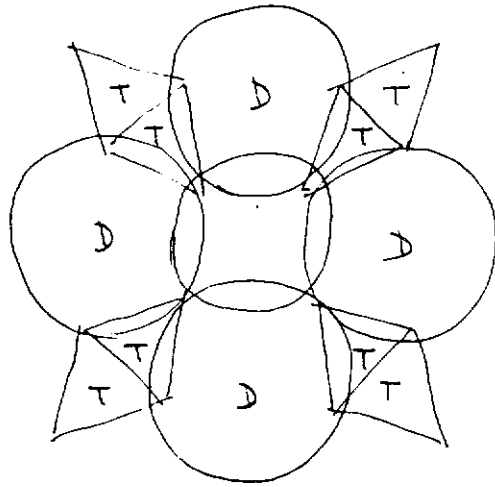


PLAN

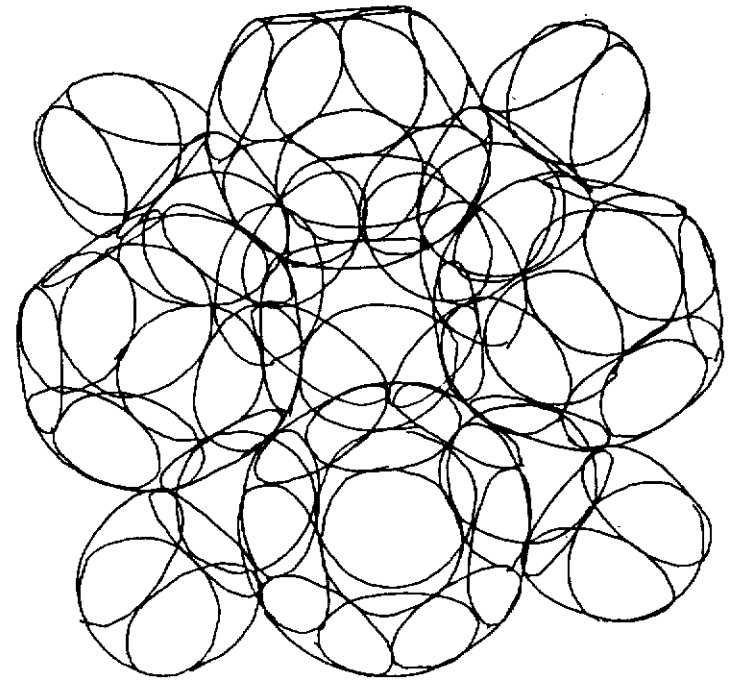


5 DODECAHEDRA
10 HEXAEDRA
5 TETRAHEDRA

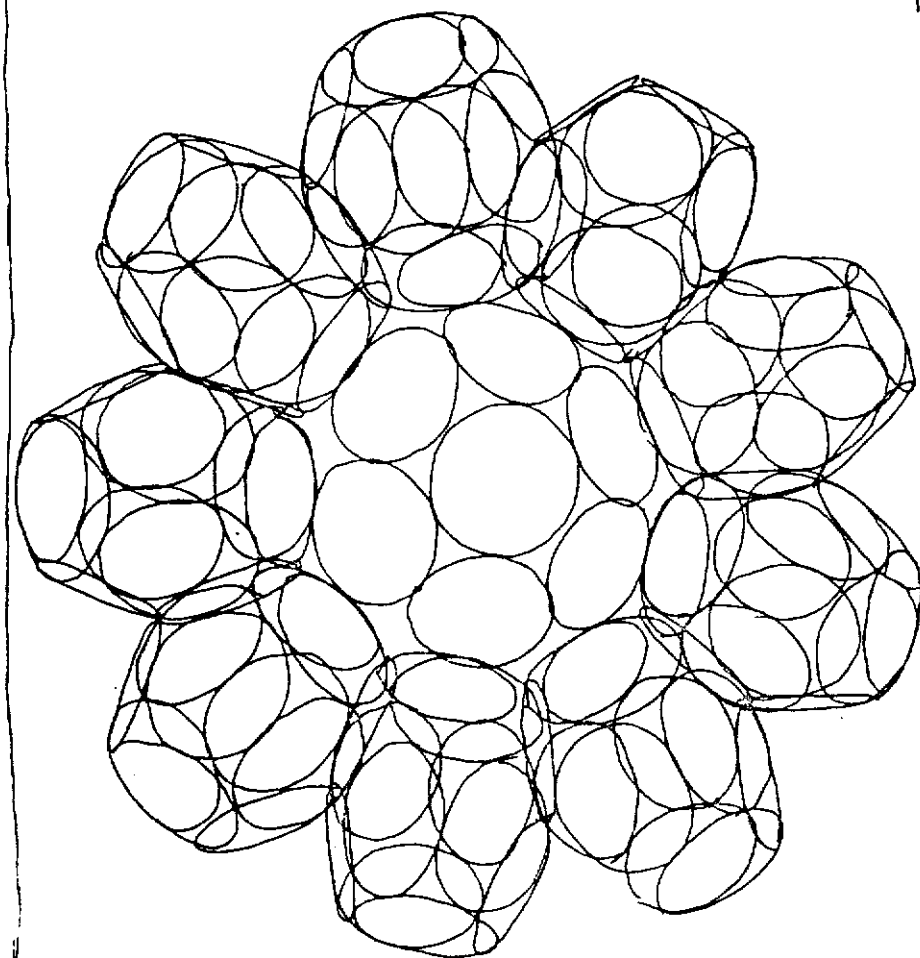
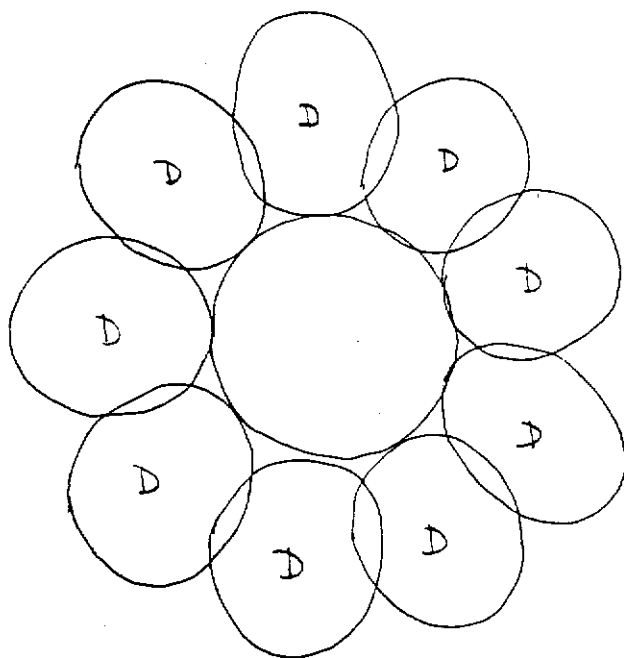
SCHEMA



PLAN

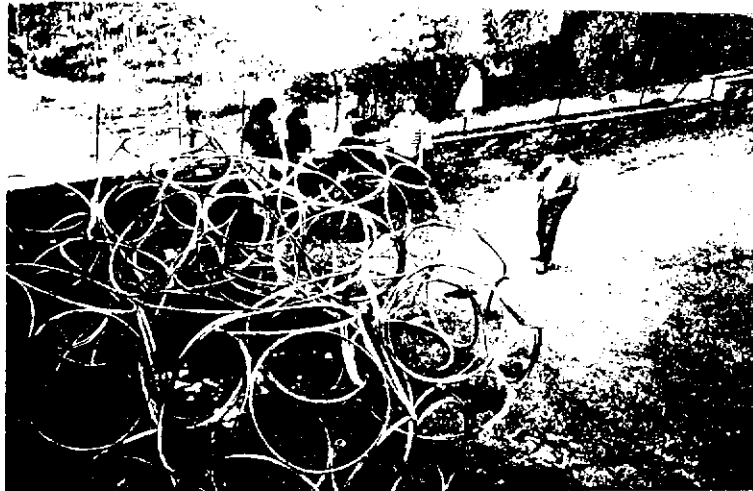
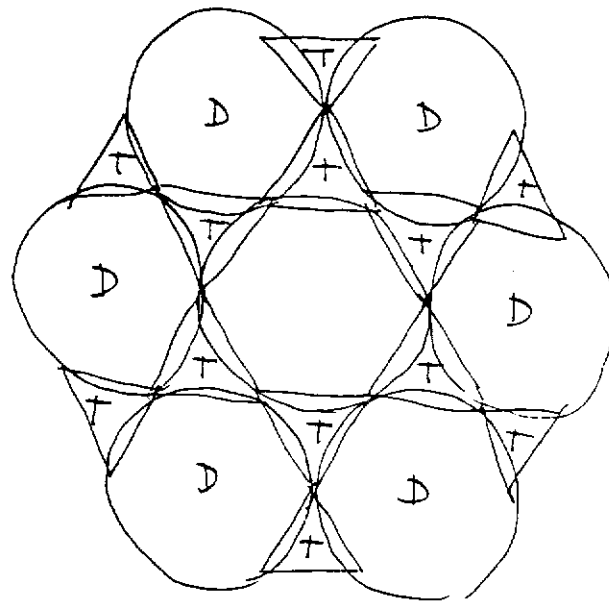


4 DODECAHEDRA
8 TETRAHEDRA

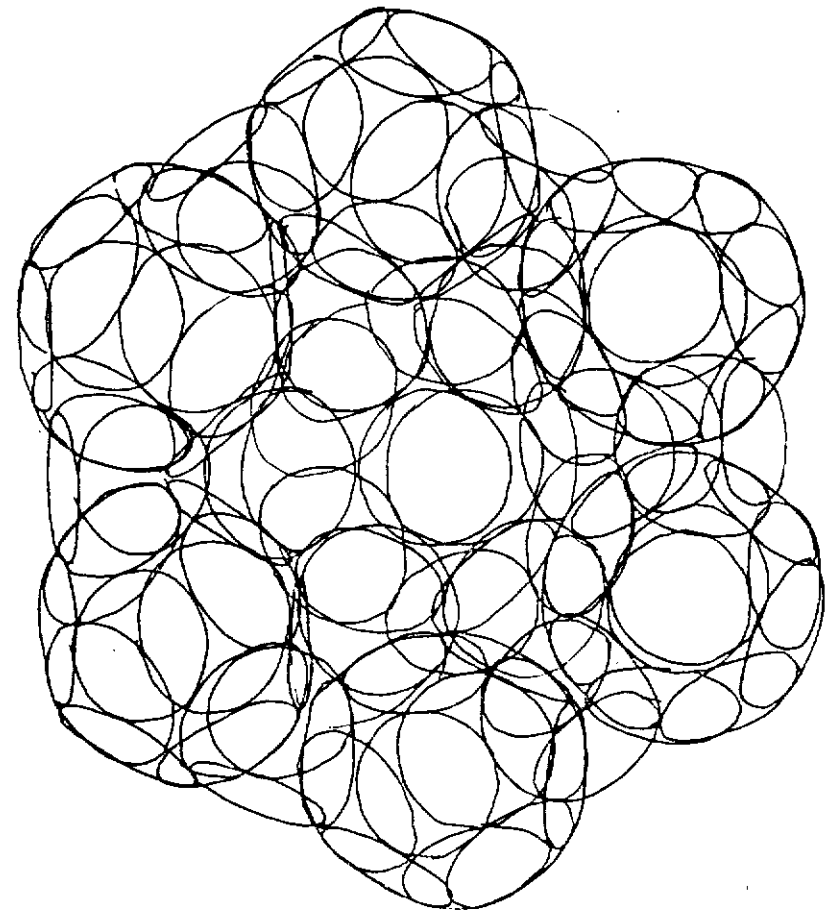


9 DODECAHEDRA

SCHEMA

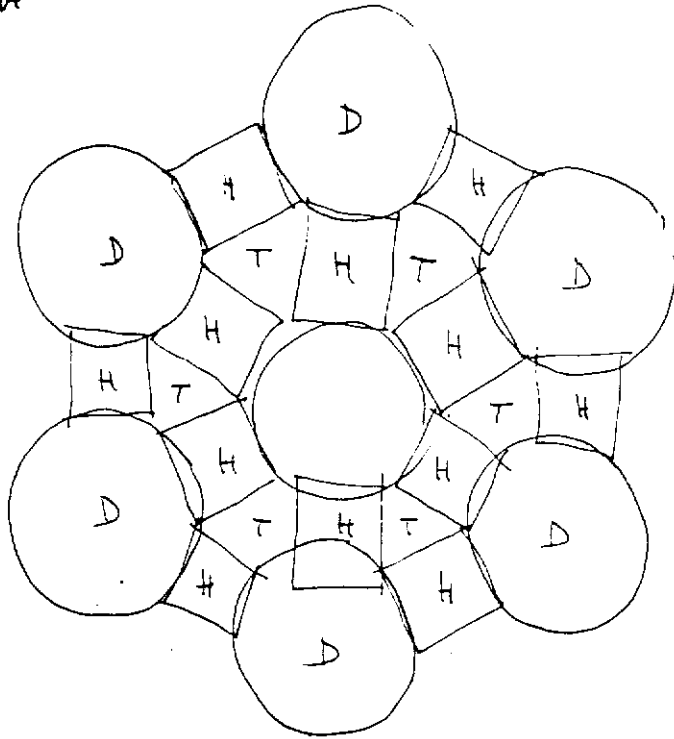


PLAN

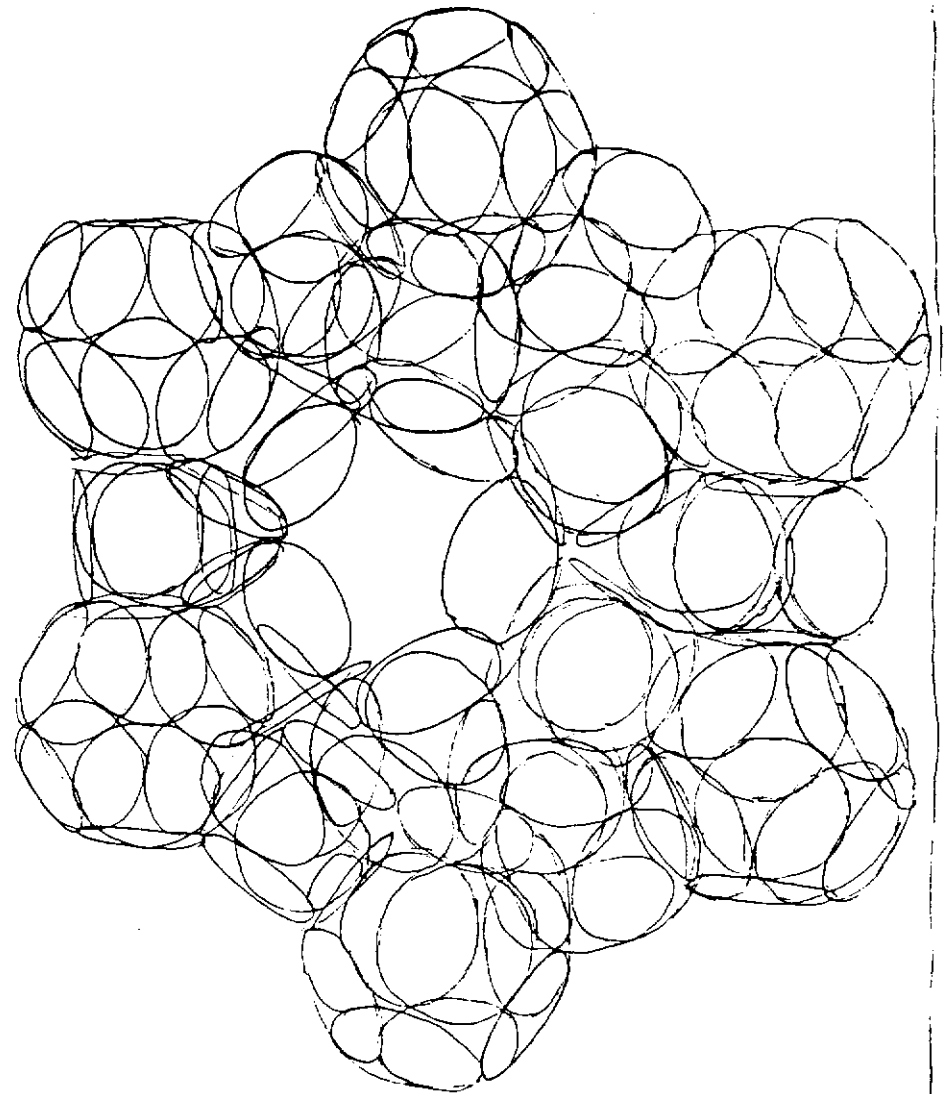


6 DODECAHEDRA
12 TETRAHEDRA

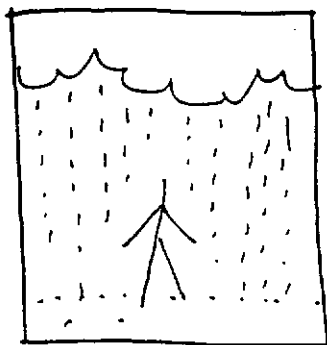
SCHEMA



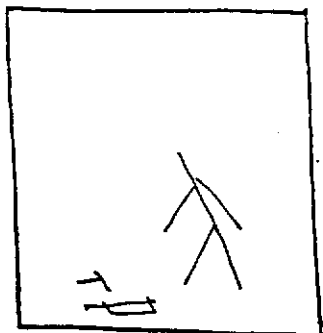
PLAN



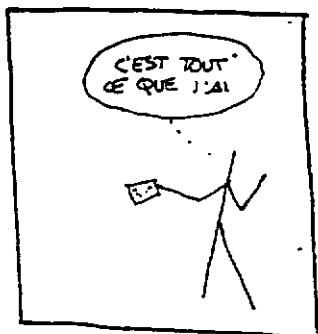
6 DODECAHEDRA
12 HEXAHEDRA
6 TETRAHEDRA



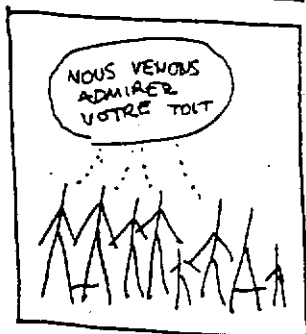
YOU WANT TO BUILD
A ROOF,



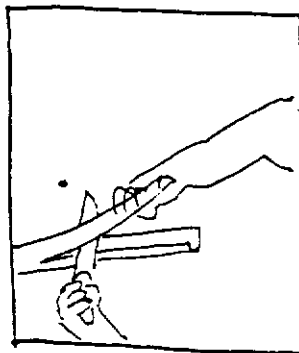
WHICH IS QUITE SIMPLE
TO DO WITHOUT SPECIALIST'S HELP



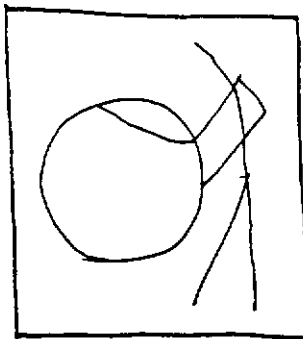
AND WHICH SHOULD BE INEXPENSIVE



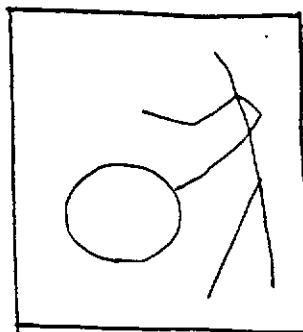
AND SHOULD LOOK INTERESTING



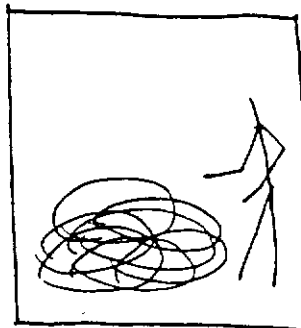
YOU CAN START TO MAKE,
WITH SPLIT BAMBOO
OR WITH THIN BRANCHES,



RINGS
OF A DIAMETER ABOUT 3 FEET
(1 METER);

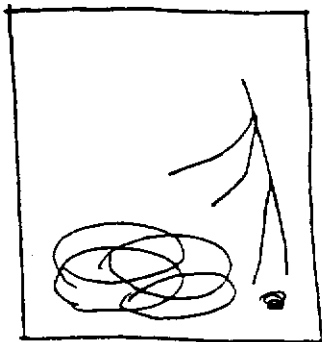


IF THE MATERIAL (BAMBOO OR WOOD)
IS NOT STRONG ENOUGH,
YOU CAN MAKE A RING
WITH A SMALLER DIAMETER



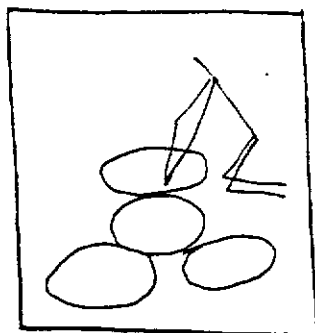
YOU SHOULD PREPARE
A CERTAIN NUMBER OF SUCH RINGS:

THE NUMBER WILL DIFFER
ACCORDING THE MODEL (SEE ANNEX).



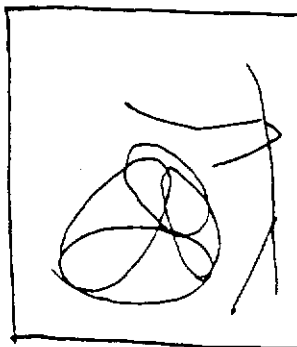
TO START WITH,
YOU HAVE TO TIE TOGETHER
4 RINGS,

WITH WIRE
OR WITH A SOLID ROPE.



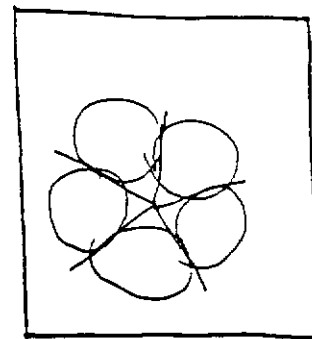
IN ORDER TO DO SO,
YOU DISPOSE THE RINGS
ON THE FLOOR,
LIKE ON THE DRAWING,

AND YOU TIE THEM TOGETHER
WHERE ONE RING TOUCHES ANOTHER.

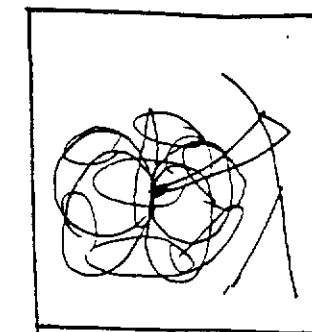


YOU OBTAIN THUS A RIGID STRUCTURE
MADE WITH THE 4 RINGS

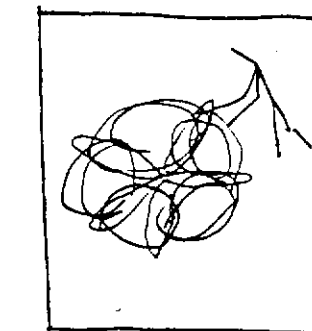
(A SORT OF A TETRAHEDRON).



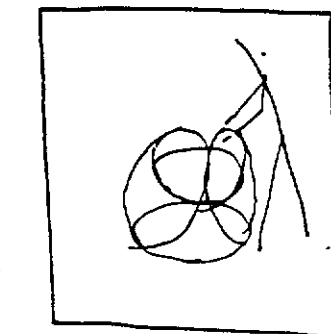
YOU SHOULD MAKE 5 OF THEM
AND DISPOSE THEM
IN THE PATTERN OF A FLOWER,



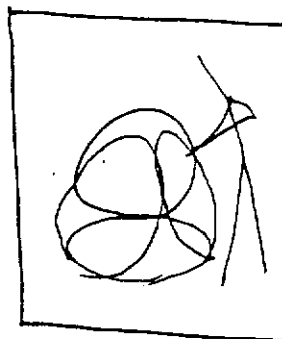
THEN TIE THEM TOGETHER
IN THE CENTER OF THAT PATTERN
WHERE THE 5 TETRAHEDRA MEET.



THEN, YOU START TO TIE TOGETHER
THE OTHER RINGS,



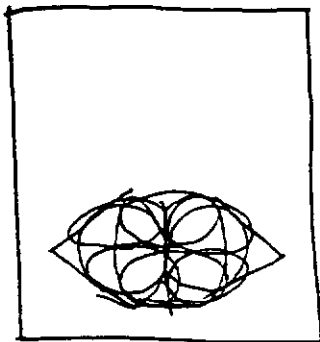
THEN
YOU LIFT THE 3 EXTERNAL RINGS,
LEAVING THE CENTRAL ONE
ON THE FLOOR.



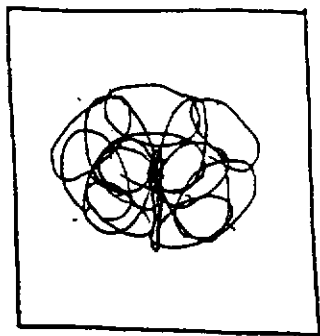
THE RINGS WHICH YOU HAVE LIFTED
WILL TOUCH IN PAIRS,
ALTOGETHER IN 3 PLACES.

HAVING THEM IN THIS POSITION,
YOU SHOULD TIE THEM TOGETHER.

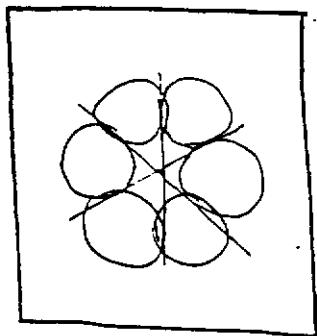
FIRST THOSE ON THE TOP
THEN THOSE BELOW.



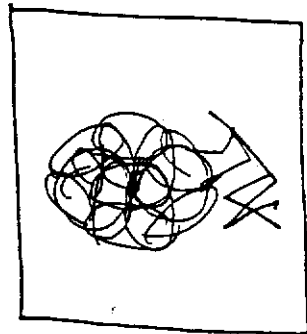
YOU OBTAIN BY DOING SO
A STRUCTURE
IN THE FORM OF A "LENS".



THIS IS A VERY SOLID STRUCTURE;

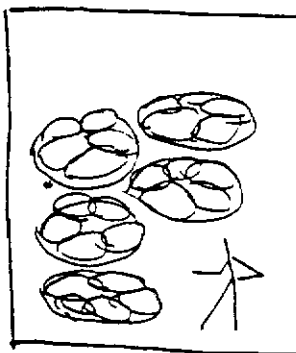


ONE CAN BUILD SUCH LENTILS
WITH 6 TETRAHEDRA
AS WELL,

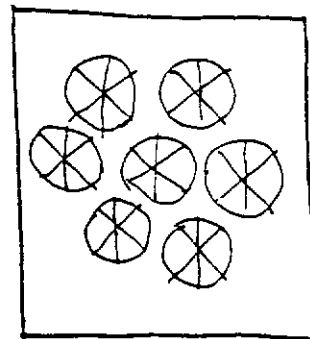


DISPOSED AS IN THE DRAWING.

ONE HAS TO SQUEEZE THEM
SOMEWHAT,
IN ORDER TO TIE THEM TOGETHER.

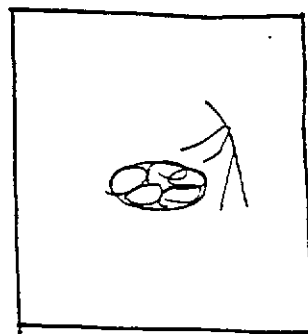


LET US CONTINUE

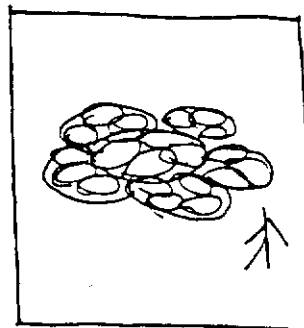


FIRST, YOU SHOULD MAKE 6 LENTILS
(EACH WITH 5 TETRAHEDRA,

OR 7 LENTILS,
EACH WITH 6 TETRAHEDRA,
WHICHEVER SUITS YOU BEST).

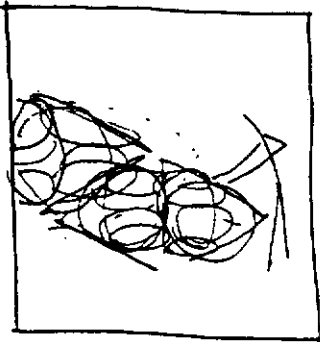


YOU TAKE THE FIRST LENTIL,
WHICH WILL SERVE AS CORE,

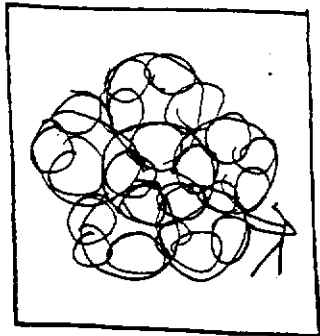


AND YOU FIX ON EACH OF ITS
DOWNSIDE RINGS

THE UPSIDE RING
OF EACH OF THE OTHER LENTILS.

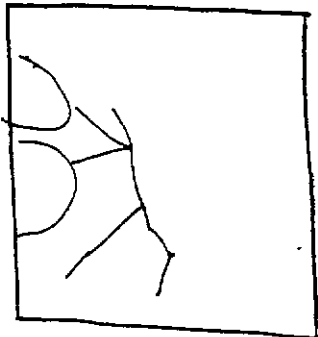


YOU TIE THE 5 LENTILS
ONTO THE CORE LENTIL,

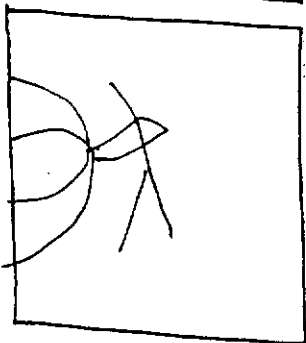


THEN YOU TIE TOGETHER
THOSE LENTILS

IN EVERY SPOT
WHERE 2 RINGS MEET.

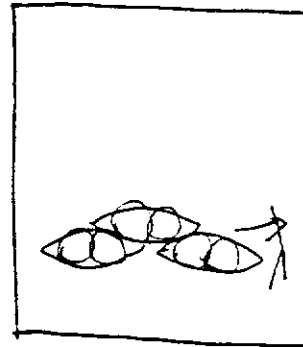


OFTEN THE ELEMENTS OF THAT STRUCTURE
HAVE TO BE DRAWN TIGHTLY TOGETHER

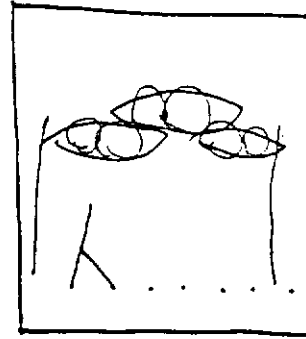


TO AVOID GAPS
BETWEEN RINGS.

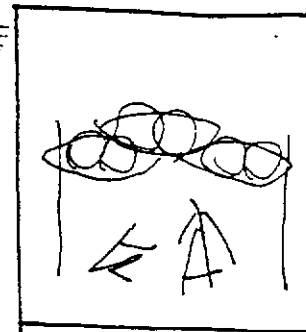
THE TENSION THUS CREATED
MAKES THE STRUCTURE MORE RIGID.



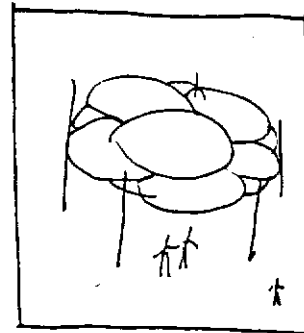
YOU OBTAIN THUS
A VERY SOLID STRUCTURE



WITH A SPAN
OF ABOUT 18 FEET (6 METRES),

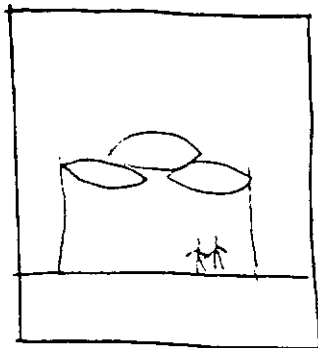


WITH VERY THIN COMPONENTS.

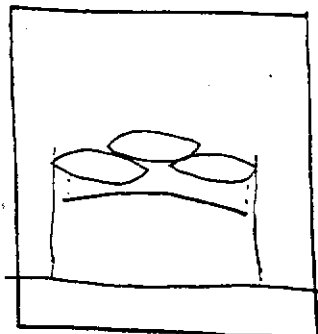


THIS STRUCTURE
CAN BE SUPPORTED BY WALLS

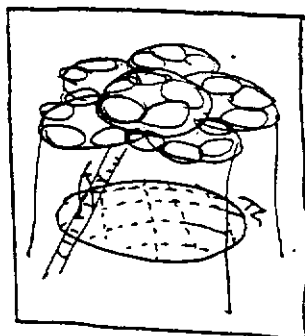
OR BY POSTS.



THE STRUCTURE
WHICH YOU HAVE BUILT

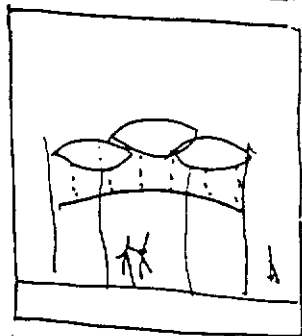


WILL SUPPORT THE "ROOF-SKIN",

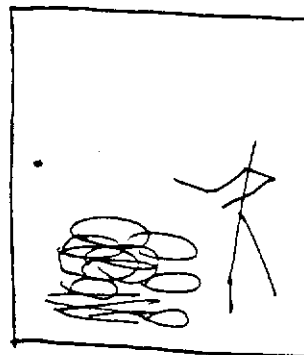


MADE WITH MATS,
WITH PLASTIC FOILS
OR WHATEVER YOU PREFER.

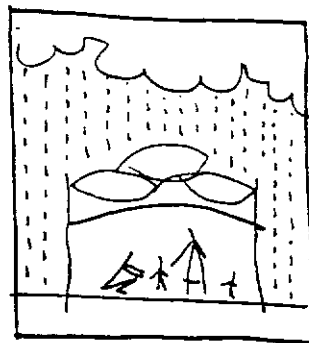
THIS "SKIN"
HAS THE FORM OF A FLAT DOME



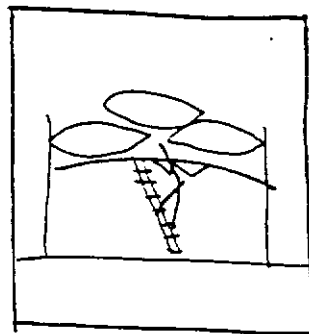
WHICH WILL HANG
ON THE STRUCTURE YOU BUILT.



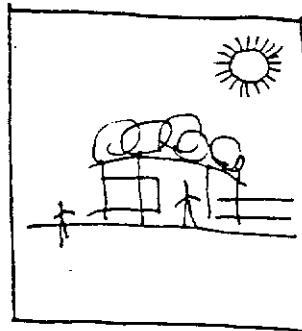
THUS, USING LITTLE MATERIAL



YOU CAN BUILD A ROOF,
WHICH IS SOLID
AND WHICH PROTECTS YOU,



EASY TO REPAIR,



AND WHICH WILL LOOK NICE.



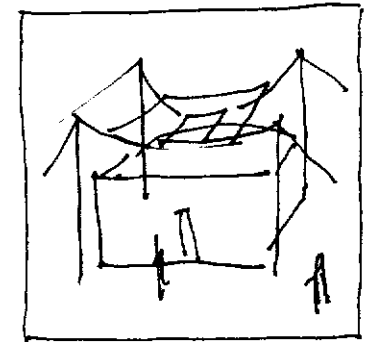
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

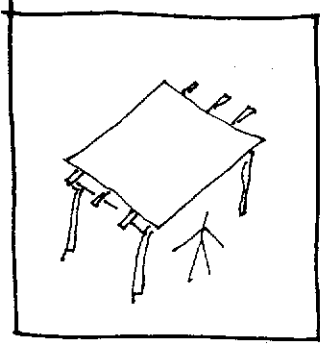


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

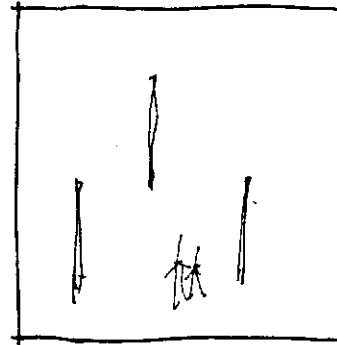
33, BD GARIBALDI, 75015 PARIS ☎ (331) 783-20-24

SUSPENDED ROOFS,

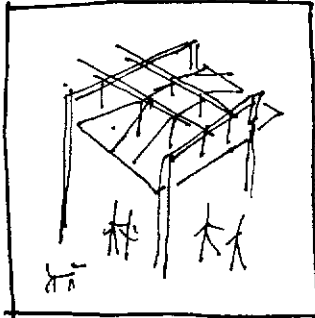




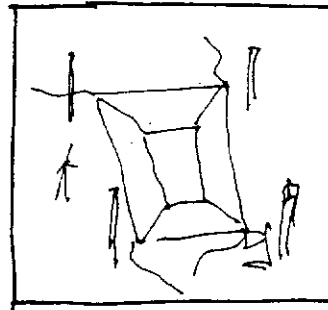
A ROOF COVER
CAN BE SUPPORTED BY BEAMS.



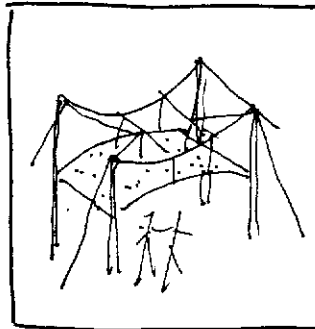
TO SUSPEND SUCH A SUPPORTING NET
YOU WILL NEED, AT LEAST, 3 POSTS
TO WHICH THE NET WILL BE FASTENED



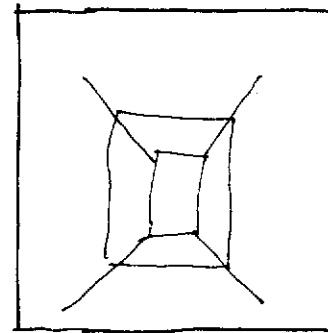
BUT IT CAN ALSO BE
SUSPENDED FROM.



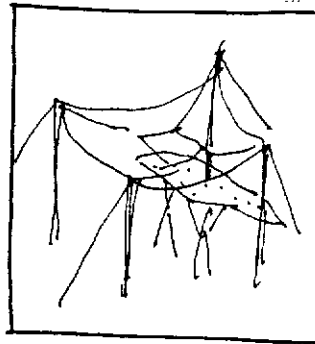
THE NET CAN HAVE A LAYOUT
OF CONCENTRIC POLYGONES,
HAVING AS MANY CORNERS
AS MANY POSTS AS YOU INTEND TO USE



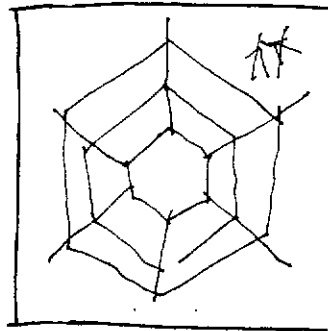
IN THE LATTER CASE
YOU CAN MAKE
AN ALL-ROPE ROOF,



THE NET WILL CONSIST
OF THESE POLYGONES,
LINKED WITH DIAGONALS
ACCORDING TO THE NUMBER OF POSTS.

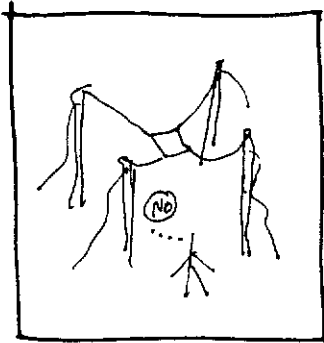


MAKING WITH SOLID ROPE
A SIMPLE NET

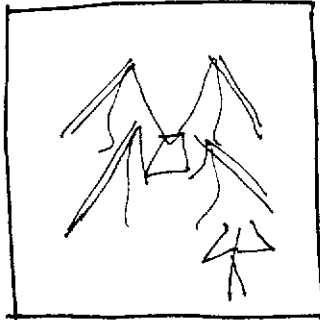


THAT NET WILL LOOK
LIKE A LARGE SPIDERS' WEB.

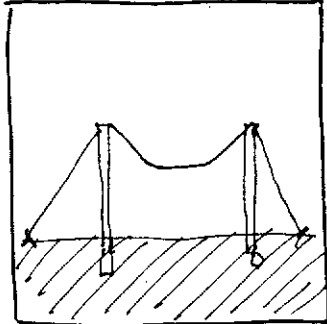
FROM WHICH THE ROOF COVER WILL HANG.



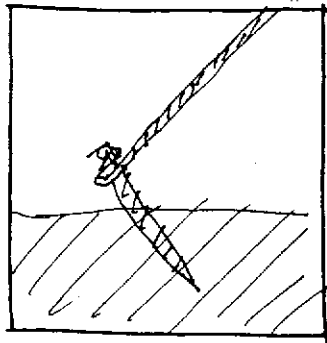
YOU CANNOT HANG, WITHOUT PRECAUTIONS,
THAT NET SIMPLY ONTO THE POSTS:



IT WOULD DRAW, BY ITS SHEER WEIGHT,
THE POSTS INWARDS
AND MAKE THEM COLLAPSE.

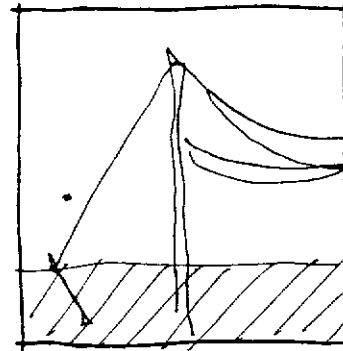


TO COUNTERACT THAT FORCE
YOU HAVE TO FIX
THE END OF EACH ROPE

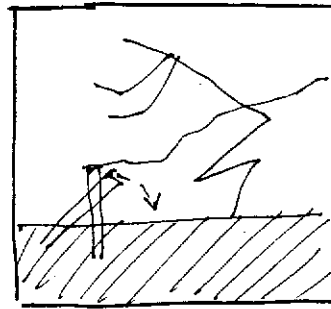


TO A SOLID ANCHOR
FIXED INTO THE GROUND

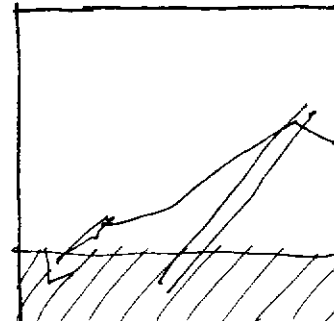
(AS YOU WOULD ANCHOR
A TENT).



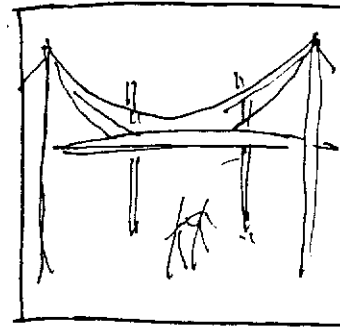
THUS ANCHORS HAVE TO BE
DRIVEN DEEP INTO THE GROUND



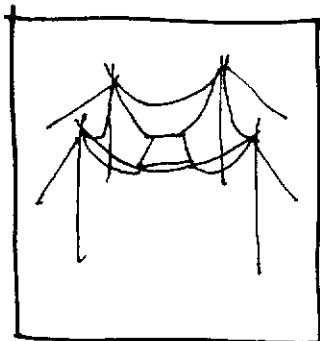
TO AVOID THEIR SLIPPING OUT



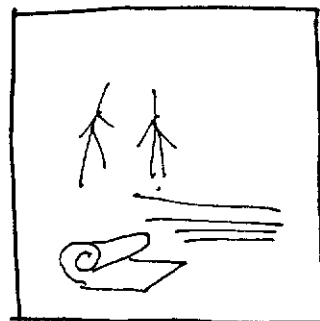
OR TEARING AWAY



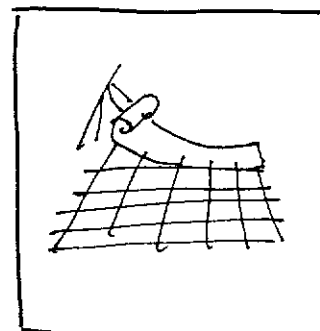
UNDER THE EFFECT
OF THE WEIGHT OF THE ROOF.



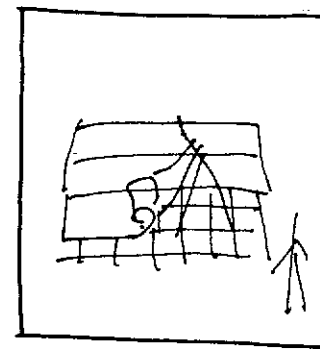
ONCE THE SUSPENSION NET
FIRMLY FIXED
TO POSTS AND ANCHORS,



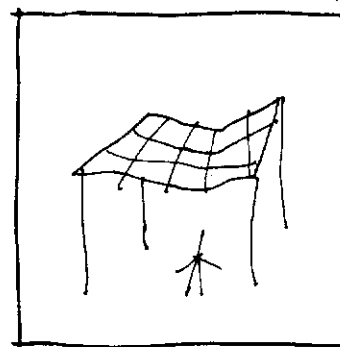
YOU SHOULD PREPARE
THE ROOF COVER,



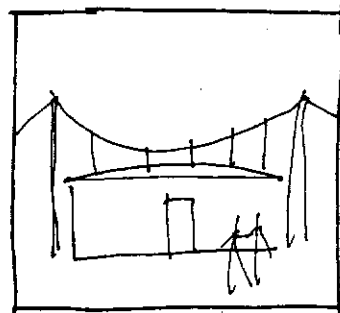
FOR EXAMPLE,
WITH WATERPROOF MATS
ON A NEARLY FLAT LATTICE SHELL.



(NOTE:
IF THE LATTICE IS NOT FLAT ENOUGH
IT WOULD BE DIFFICULT
TO FOLLOW, WITH MATS,
ITS FORM).

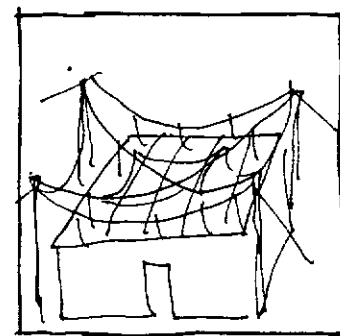


BUT, A NEARLY FLAT LATTICE SHELL
IS NOT SOLID
OVER A LARGE SPAN
(FOR EXAMPLE, ONE NEEDED
TO COVER A HOUSE).

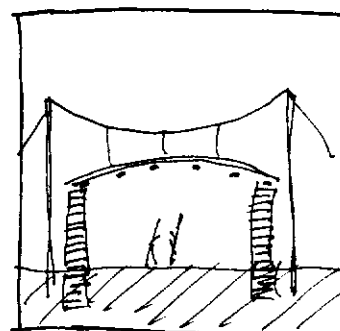


SUCH A FLAT LATTICE SHELL
CAN BE SOLID
IF IT IS SUPPORTED IN MANY PLACES
EITHER BY POSTS

OR BY SUSPENSION.

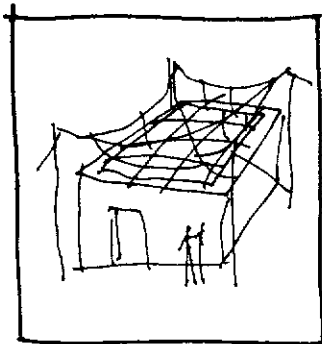


IN THE CASE WE EXAMINE,
IT WILL BE SUPPORTED
BY SUSPENSION:

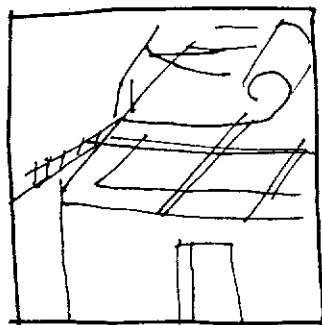


IF THE LATTICE SHELL WITH THE MATS
IS SUSPENDED
IN MANY PLACES
ON THE SUSPENSION NET,

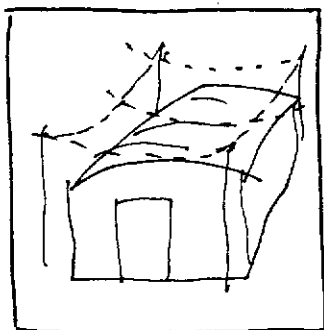
IT WILL BE QUITE SOLID.



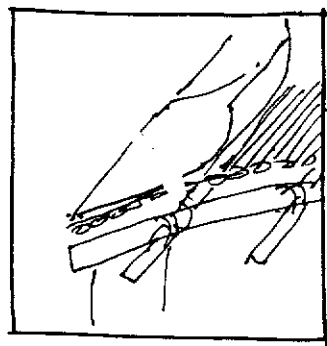
IT IS NOT DIFFICULT
TO COVER THE LATTICE SHELL
WITH MATS
OR OTHER SHEET MATERIAL,



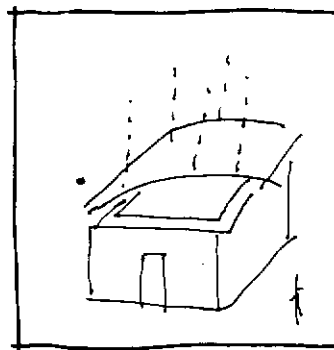
TO MAKE A ROOF
FOR YOUR HOUSE.



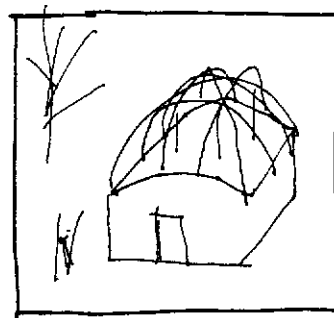
THE LATTICE SHELL WITH THE MATS
(COMBINED WITH WATERTIGHT FOIL)



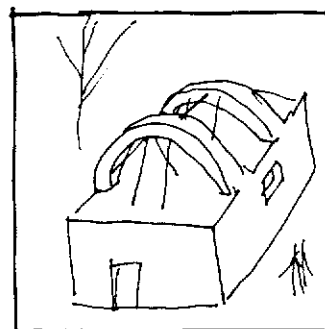
WILL MAKE A SOLID ROOF
EASY TO MAINTAIN.



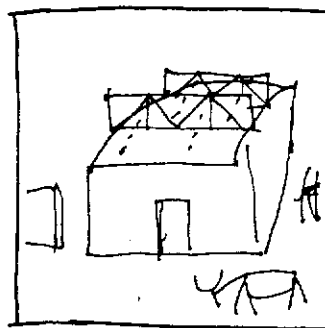
OBVIOUSLY ENOUGH,
SUCH A FLAT LATTICE SHELL



CAN BE SUSPENDED
FROM OTHER KINDS
OF SUPPORTING STRUCTURES TOO:

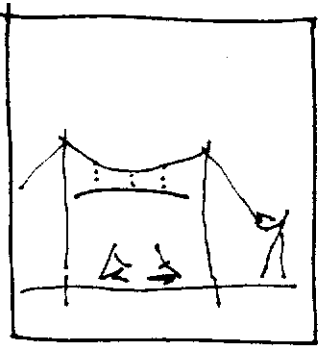


LIKE DOMES,
ARCHES,

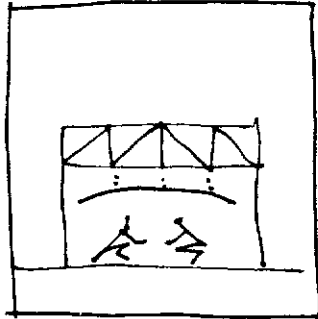


OR SPACE-FRAME GIRDERS.

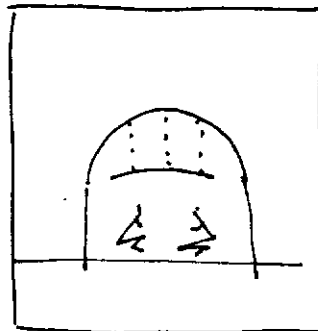
A ROOF CAN BE SUSPENDED
FROM NEARLY EVERY KIND OF SUPPORT.



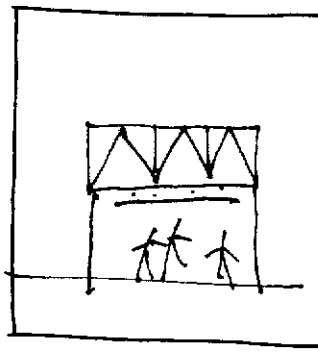
IF YOU WANT TO BUILD
A SUSPENDED ROOF,
WITHOUT HAVING TO ANKHOR IT,



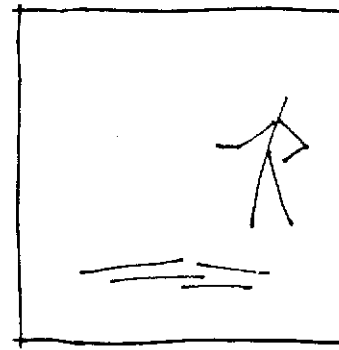
YOU CAN SUSPEND THE ROOF
ON STIFF SUPPORTING STRUCTURES,



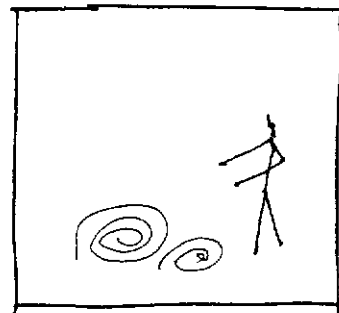
LIKE ARCHES, DOMES



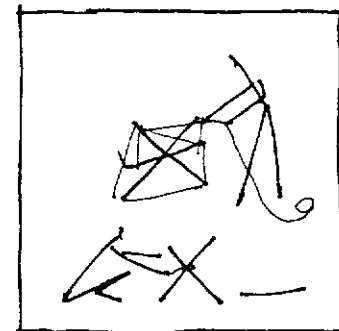
OR SPACE-FRAME GIRDERS.



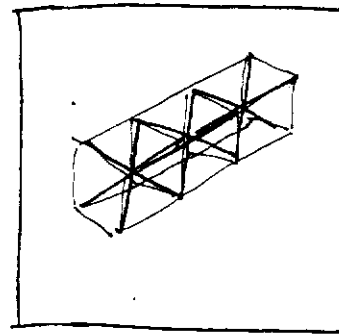
A PARTICULAR KIND OF SPACE-FRAME
USES LITTLE WOOD
(OR ANY SIMILAR STUFF),



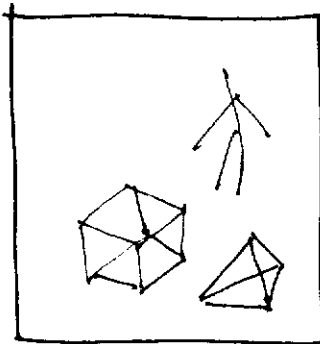
SUBSTITUTING ROPES
FOR A PART OF THE RIGID MEMBERS.



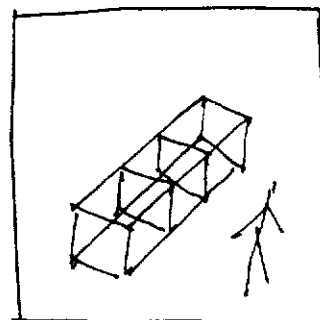
SUCH SPACE FRAMES
ARE MORE COMPLICATED TO BUILD,



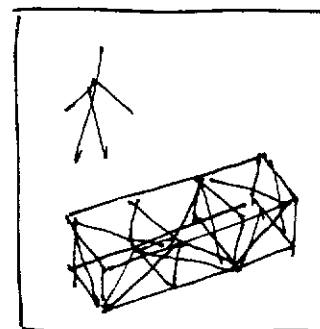
BUT THEY ARE MATERIAL-SAVING.



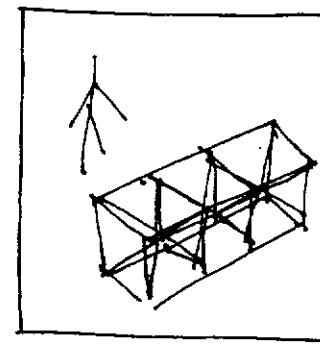
AN ORDINARY SPACE-FRAME
CONSISTS, ROUGHLY, OF POLYHEDRA



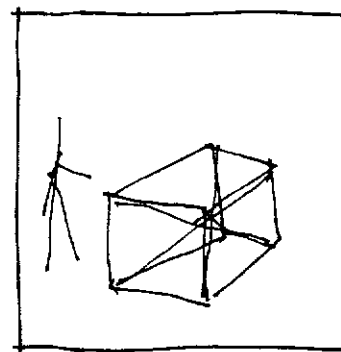
THE SIMPLEST TO DRAW
IS A ROW OF CUBES,



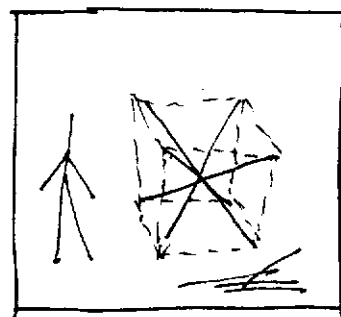
WITH THEIR DIAGONALS,



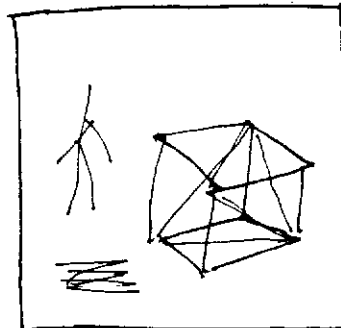
EITHER THOSE PLANE TO THE FACES,
OR THOSE
PASSING THROUGH THE INSIDE
OF THE CUBE.



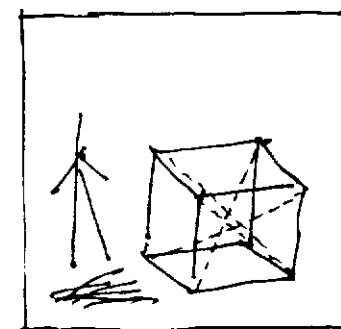
THESE SPACE-FRAMES,
CUBES AND DIAGONALS,
ARE MADE OF RIGID MEMBERS.



BUT, EITHER THE EDGES,

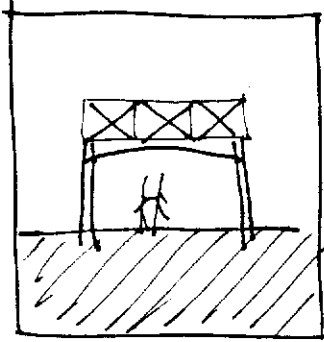


OR THE DIAGONALS
IN THE PLANE OF THE FACES

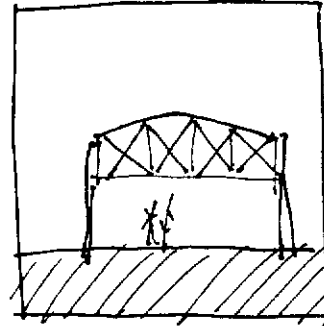


COULD BE MADE
WITH ROPES ONLY,

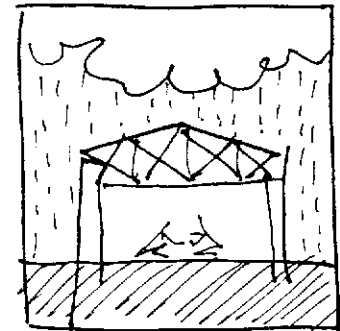
OR, EVEN THE DIAGONALS
PASSING INSIDE THE CUBE.



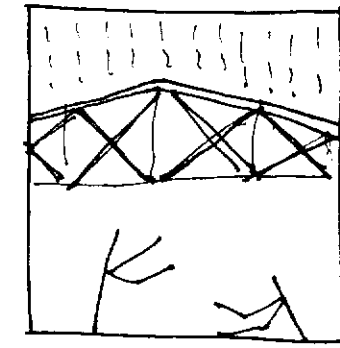
SUCH "ROPE-AND-ROD" STRUCTURES
CAN WELL SERVE
TO SUPPORT A SUSPENDED ROOF,



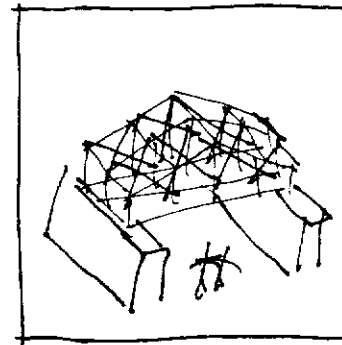
BUT IT MIGHT BE MORE PRACTICAL,
THAT THE STRUCTURE
SUPPORT THE ROOF FROM BENEATH.,



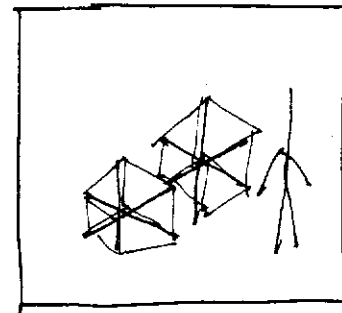
THAT KIND OF STRUCTURE
MIGHT BE TOO SENSITIVE
TO THE WEATHER,
IF ABOVE THE ROOF-COVER :



BELOW THE ROOF
IT IS WELL PROTECTED.

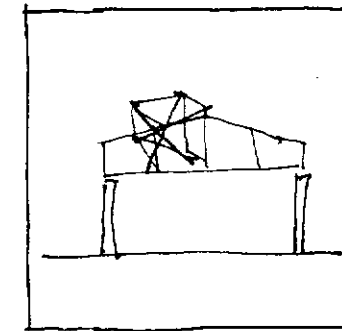


IF USED BENEATH THE ROOF COVER,
THE ROPE-AND-RODS STRUCTURE
CAN HAVE A BETTER ADAPTED SHAPE,

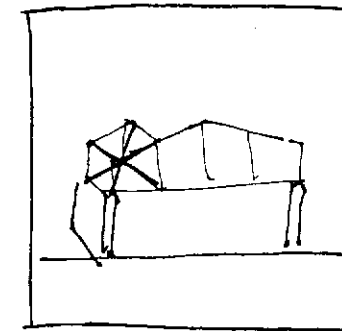


MADE OF CUBES
OF SLIGHTLY VARYING SIZES :

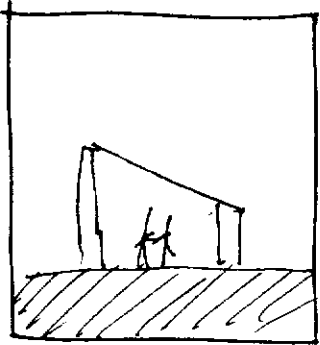
THUS YOUR ROOF
WILL HAVE THE SLOPE
FOR THE RAINWATER TO RUN OFF.



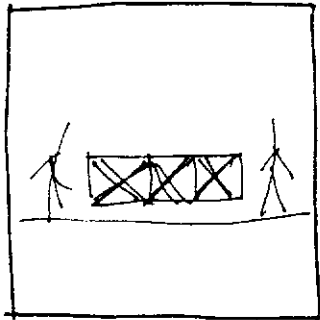
IN THIS CASE
THE CENTRE CUBES
WILL BE SLIGHTLY HIGHER



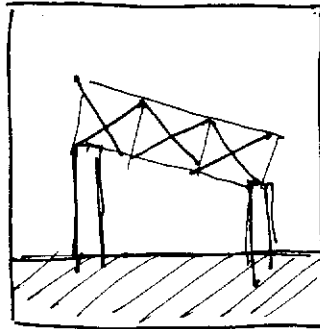
THAN THOSE ALONG THE EDGES.



IT IS OBVIOUS
THAT A ROOF CAN BE MADE
WITH A SLOPE TO ONE SIDE ONLY.

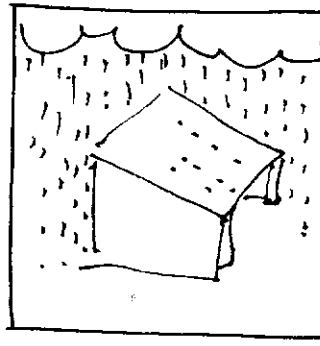


THEN YOU DONT NEED
TO MAKE THE GIRDER ITSELF SLOPING,



IT IS SUFFICIENT
TO HAVE THE BEARING WALLS UNEVENLY HIGH.

YOU PLACE THE ROOF COVER
ONTO THE SLANTED GIRDER.



SLANTED ENOUGH
TO MAKE THE WATER RUN DOWN.



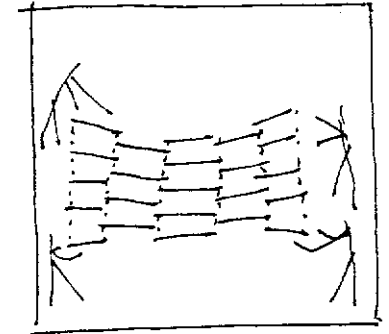
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



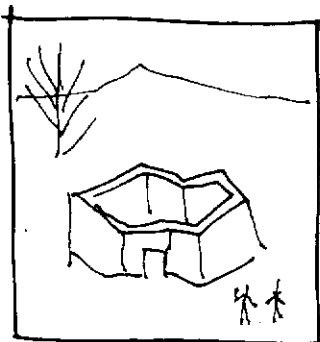
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

33, BD GARIBOLDI, 75013 PARIS ☎ (331) 783-20-24

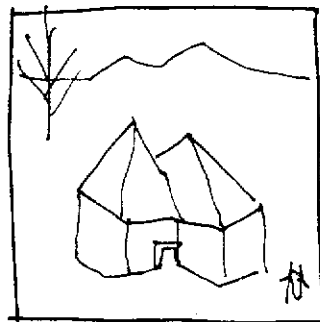
FREELY SHAPEABLE GRIDS



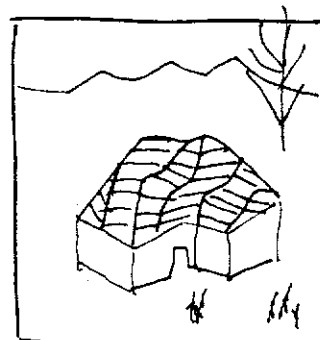
BASIC RESEARCH: Y. S. LEBEDEV
LABORATORY FOR ARCHITECTURAL BIONICS
MOSCOW



TO BUILD A ROOF
ON AN IRREGULAR OUTLINE
IS A DIFFICULT TASK,

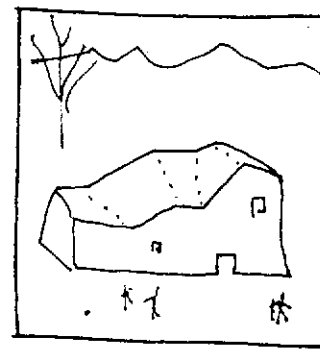


IF TACKLED
WITH ORDINARY TECHNIQUES.



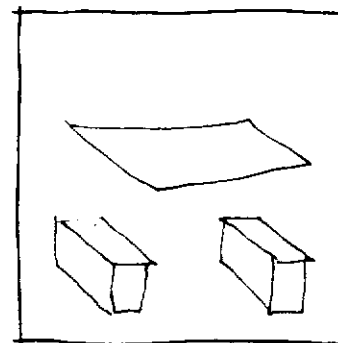
IT IS POSSIBLE TO BUILD
GRIDS OF A PARTICULAR KIND,
WHICH CAN TAKE
A WHOLLY IRREGULAR SHAPE,

EITHER IN PLAN,



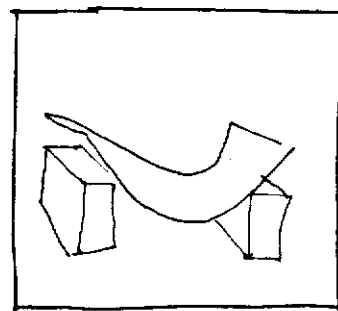
OR IN SECTION
(FOR EXAMPLE
COVERING BUILDINGS HAVING
VARIOUS HEADROOMS);

SUCH SHAPES
CAN EVEN BE ESTHETIC.

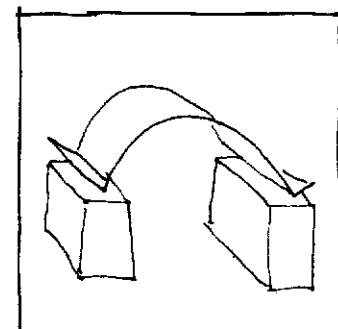


IRREGULAR SHAPES
CAN BE VERY SOLID.

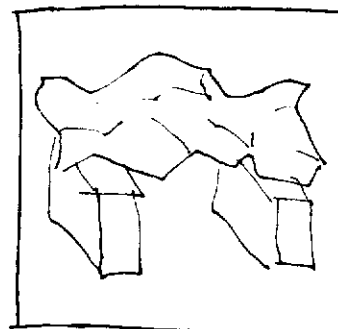
YOU CAN TEST THIS, EXPERIMENTALLY,
WHEN COVERING A SPACE BETWEEN 2 BOXES
WITH A SHEET OF PAPER.



IF YOU POSE THE PLANE P PAPER SHEET
ONTO THE BOXES,
THE SHEET WILL IMMEDIATELY
SAG IN THE MIDDLE.

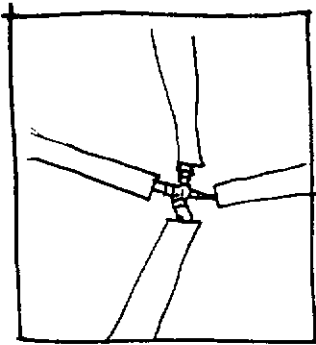


IF YOU BEND UPWARDS
THAT SAME SHEET, LIKE A VAULT
IT WILL KEEP THAT SHAPE,
PROVIDED THAT YOU FIX THE LOWER EDGES.

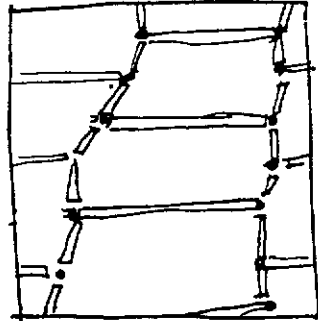


IF, ON THE OTHER HAND,
YOU CRUMPLE THAT SHEET THOROUGHLY
AND THEN DISCRUMPLE IT,
THE SHEET WILL WORK AS A SOLID COVER.

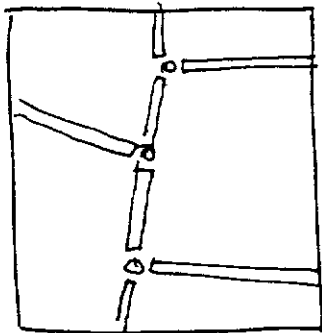
OF IRREGULAR SHAPE:



A GRID CAN WORK
LIKE THAT SHAPE OF PAPER DID,
IF THE GRID-BARS ARE LINKED
WITH SOFT JOINTS.

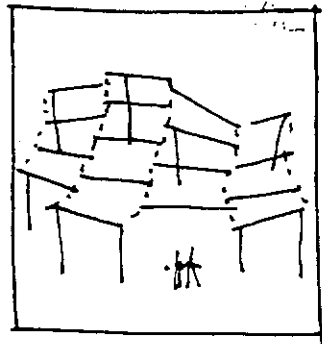


YOU CAN BUILD SUCH A GRID,
FOR EXAMPLE,
WITH LONG BARS ALONG ONE AXIS
AND SHORT ONES ALONG THE OTHER ONE.

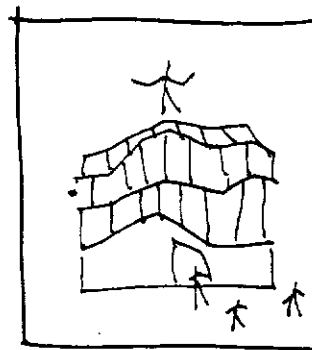


THE JOINTS LINKING THE BARS
HAVE TO BE SOFT ENOUGH
TO PERMIT FREE MOVEMENT OF THE BARS,

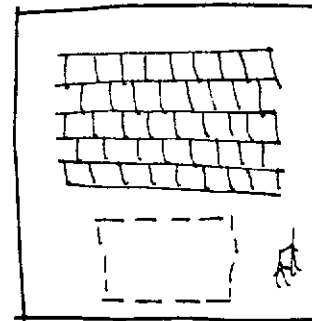
FOR EXAMPLE,
THE BARS CAN BE LINKED
WITH ROPES OR SIMILAR SOFT MATERIAL.



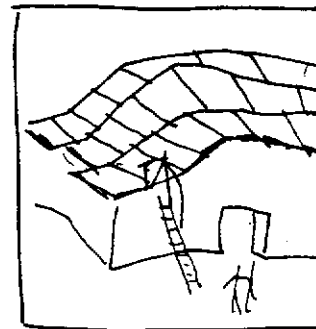
SUCH A GRID
CAN BE DEFORMED
INTO AN IRREGULAR SHAPE
AND REMAIN SOLID.



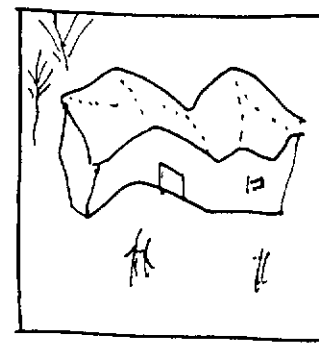
THE MAIN CONDITIONS
CONCERNING THE SOLIDITY OF THE GRID
ARE THE FOLLOWING:



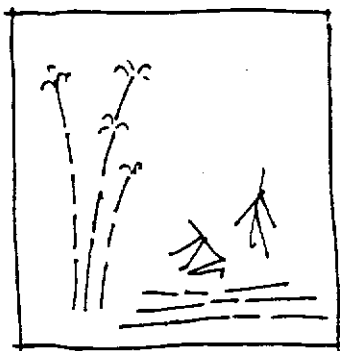
FIRST OF ALL,
THE GRID, LAID OUT FLAT ON THE GROUND
HAS TO BE LARGER
THAN THE AREA THE ROOF SHOULD COVER.



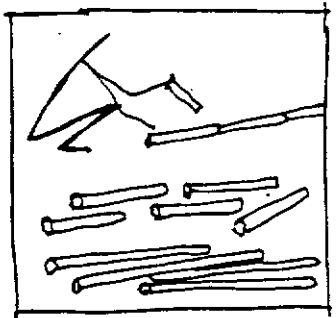
SECONDLY,
THE OUTER EDGES OF THE GRID,
ONCE IN POSITION,
SHOULD BE SOLIDLY FIXED.



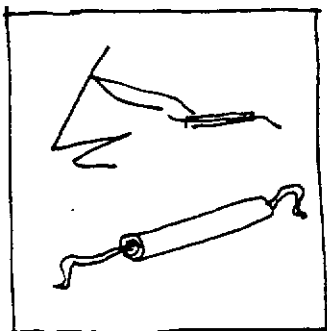
THIRD,
THE CRUMPLED SHAPE OF THE GRID
SHOULD HAVE MORE "MOUNTAINS"
THAN "VALLEYS".



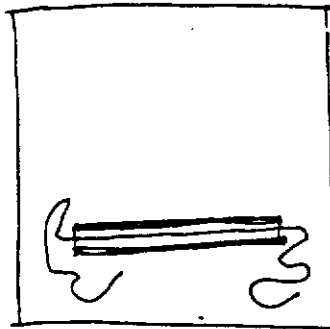
IT IS EASY TO MAKE SUCH A GRID
WITH BAMBOO.



FIRST, YOU CUT THE BAMBOO
INTO PIECES OF APPROPRIATE LENGTH:
SHORT ONES
AND LONG ONES.

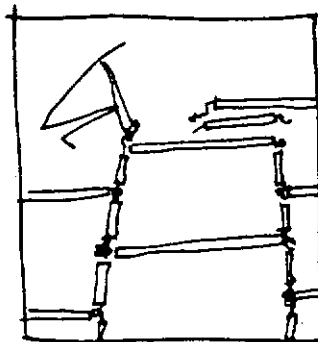


YOU PASS THEN A PIECE OF ROPE
THROUGH EACH PIECE OF BAMBOO,

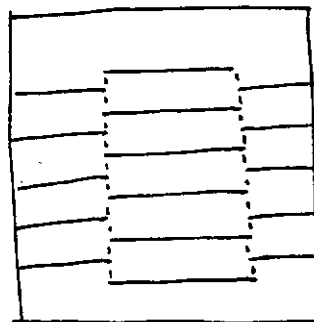


LEAVING ENOUGH LENGTH OF ROPE
AT BOTH ENDS
OF THE BAMBOO PIECE

TO TIE THE PIECES TOGETHER.

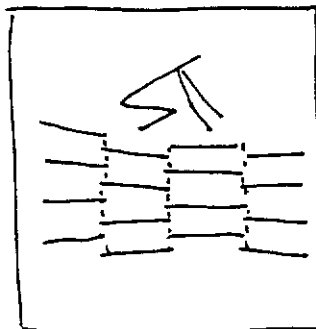


ONCE THESE PREPARATIONS ARE DONE
YOU START TO TIE TOGETHER
THE PIECES INTO A GRID,

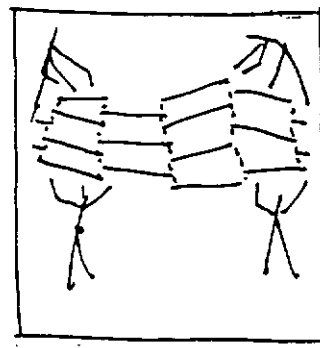


ACCORDING THE PATTERN
IN THIS DRAWING:

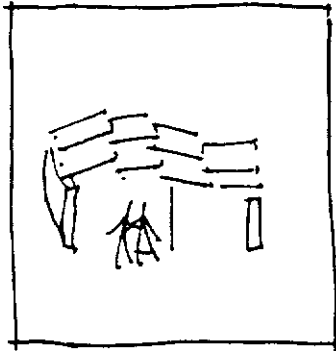
SHORT PIECES IN A LINE,
LONG PIECES ALTERNATING.



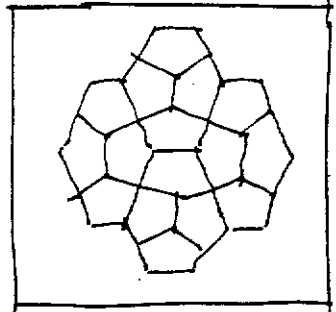
ONCE THE GRID IS
KNOTTED TOGETHER,



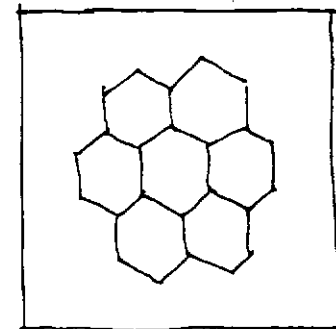
YOU CAN FORM IT
INTO VARIOUS SHAPES.



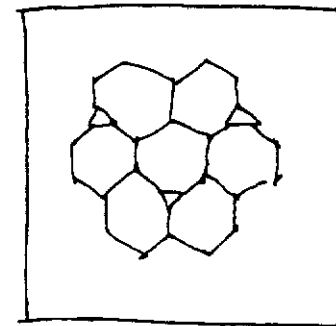
THAT PARTICULAR GRID
IS ONE OF THE SIMPLEST.
THERE ARE MANY OTHER GRIDS
WHICH BEHAVE IN A SIMILAR WAY:



GRIDS MADE WITH PENTAGONS
(5-EDGES)

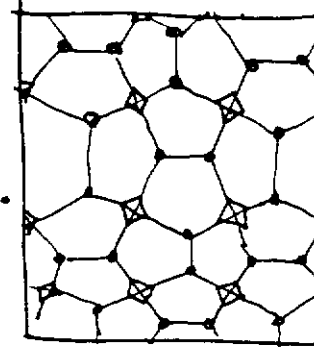


WITH HEXAGONS,
(6-EDGES)

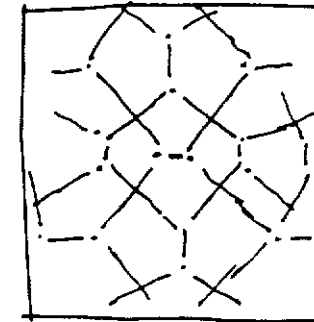


WITH HEPTAGONS,
(7-EDGES)
ETC.

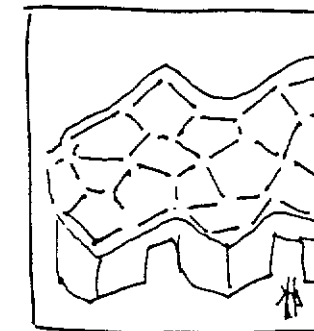
THEIR COMMON PROPERTY:
ALL OF THEM HAVE SOFT JOINTS
(AT LEAST A PART OF THEIR JOINTS).



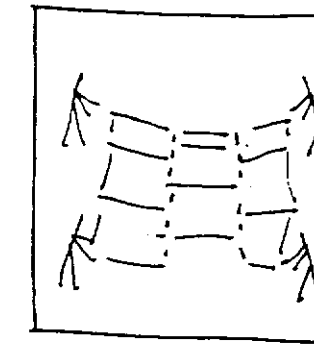
YOU CAN THUS COMBINE
STIFF JOINTS AND SOFT JOINTS



INTO VARIOUS PATTERNS.

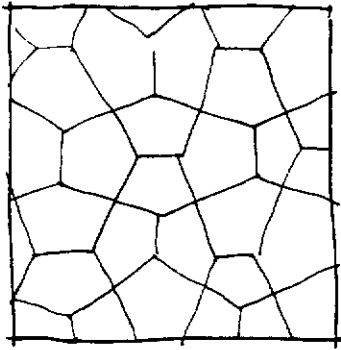


ALL OF THESE GRIDS
CAN BE ADAPTED
TO PARTICULAR ROOFSHAPES,

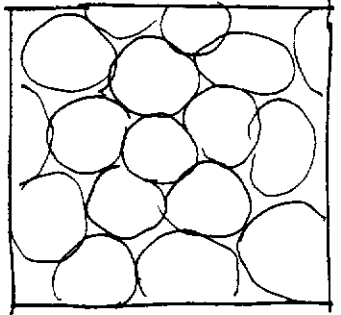


BUT THE SIMPLEST ONE IS
THE ONE EXPLAINED BEFORE
IN DETAIL,

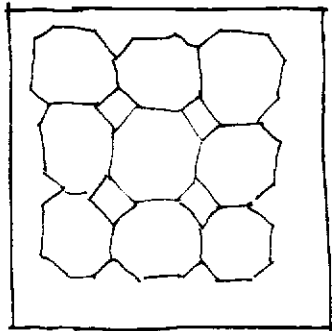
AND IS THE MOST PRACTICAL ONE.



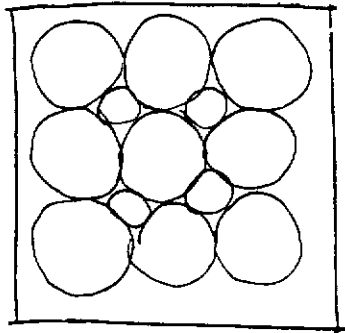
IT IS EVIDENT
THAT THOSE POLYGONES
FORMING THE GRID



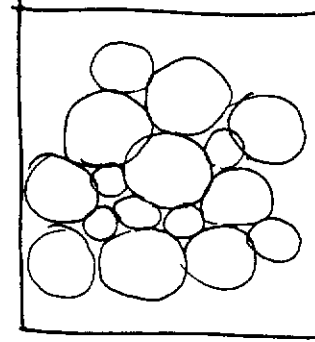
CAN BE SUBSTITUTED
BY RINGS.



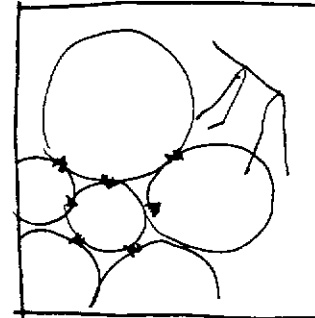
ONE CAN MAKE EQUIVALENT GRIDS
TO ALL POLYGONAL PATTERNS



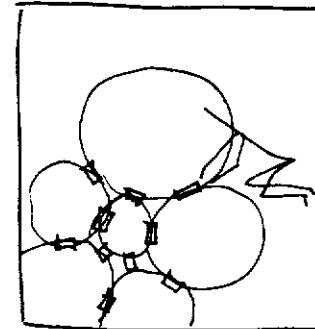
BY USING RINGS,
EVENTUALLY OF DIFFERENT SIZES.



TO BUILD SUCH A GRID, TAKE THE RINGS
AND LAY OUT AN ARBITRARY PATTERN
WITH THEM,

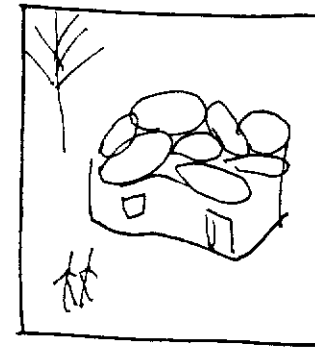


THEN FIX THOSE RINGS
AMONG THEM,



EITHER WITH SOFT JOINTS
(IF THE RINGS ARE RIGID)

OR WITH RIGID JOINTS
(IF THE RINGS ARE FLEXIBLE),



YOU OBTAIN A GRID,
WHICH WILL BEHAVE THE SAME
IN THE SAME MANNER AS THOSE
MADE WITH STRAIGHT BARS
(WHICH WE DISCUSSED BEFORE)



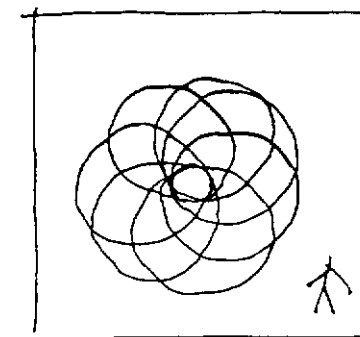
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE

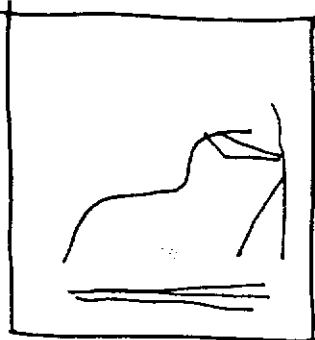


UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

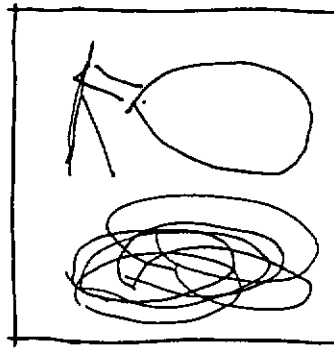
33, BD CARIBALDI, 75015 PARIS ☎ (331) 783-20-24

DOME STRUCTURES
FOR FLEXIBLE MATERIAL

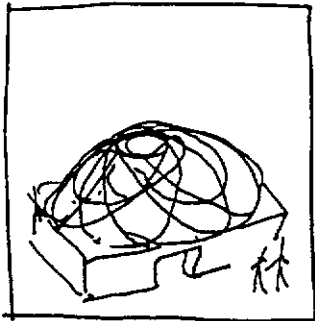




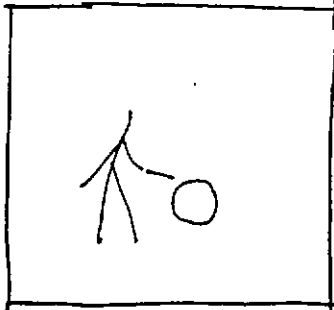
IF YOU ONLY HAVE
SOFT AND FLEXIBLE STEMS
AVAILABLE



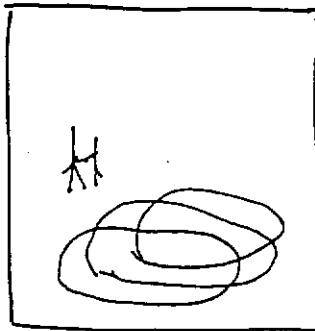
YOU WILL NEED, FOR THAT DOME,
A DOZEN OR MORE
OF SUCH LARGE RINGS,



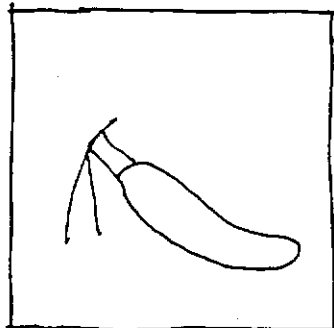
YOU CAN STILL USE THEM FOR A ROOF,
BUILDING
A VERY PARTICULAR KIND OF DOME.



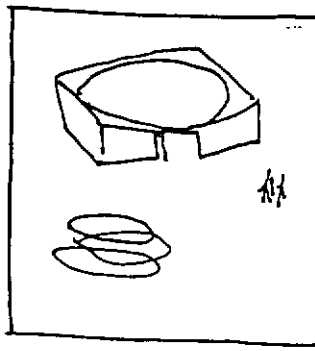
AND, ALSO ANOTHER RING,
A SMALL ONE,
HAVING A DIAMETER
OF ABOUT $\frac{1}{4}$ OF THAT OF THE LARGE RINGS.



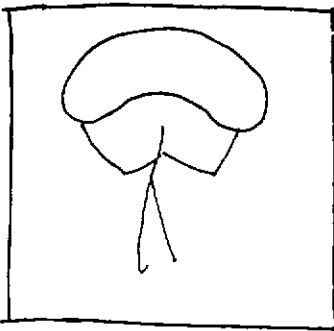
THAT DOME CONSISTS
OF LARGE AND FLEXIBLE RINGS,



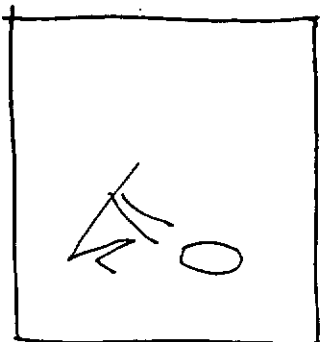
ALL THESE RINGS
ARE NOT NECESSARILY VERY STIFF



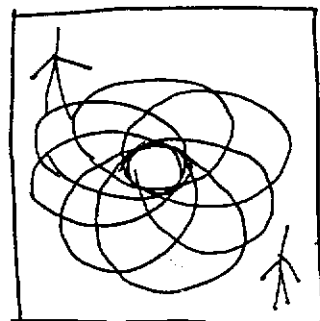
EACH RING HAVING A DIAMETER
SLIGHTLY LARGER
THAN HALF THE SPAN TO BE COVERED.



BUT RATHER ELASTIC.



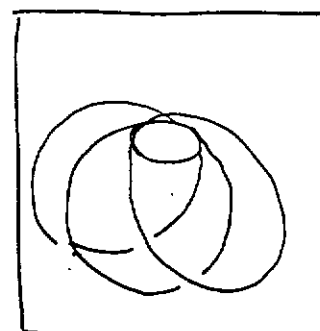
YOU SHOULD DESIGN
THE LAYOUT OF THE DOME
ON THE GROUND.



PLACE THE SMALL RING IN THE CENTRE

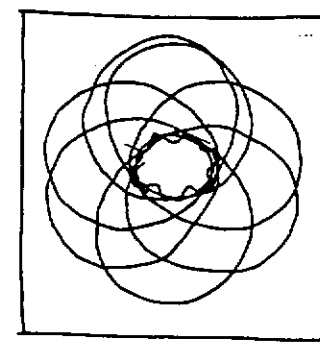
AND
YOU SHOULD DISPOSE THE LARGE ONES,
LIKE THE PETALS OF A FLOWER,
AROUND IT,

THE SMALL RING BEING INSIDE
THE LARGER ONES

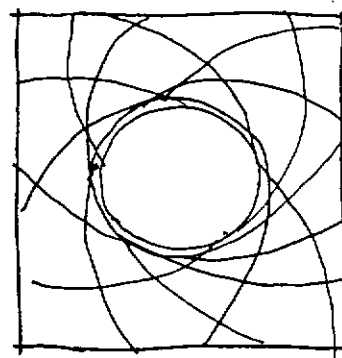


BUT TAKE CARE,
THAT EACH LARGE RING
SHOULD COVER, ON ONE SIDE,
ITS NEIGHBOURS,

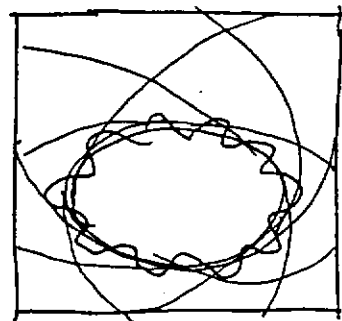
AND BE COVERED BY THEM
THE OTHER SIDE.



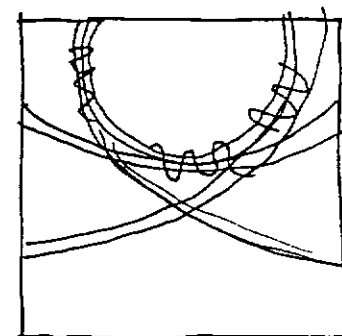
WHEN ALL THE RINGS
ARE THUS IN PLACE,
YOU SHOULD FASTEN ALL THE LARGE RINGS,
IN THAT POSITION,
TO THE SMALL RING IN THE CENTER.



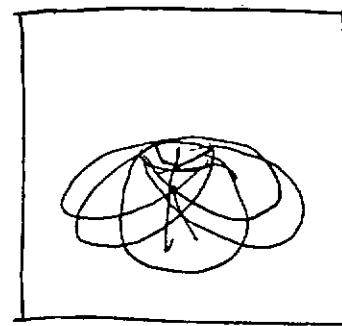
THIS FASTENING CAN BE DONE
WITH A PIECE OF ROPE,
OR WITH WIRE,



WOUND AROUND THE CENTRAL RING
AND THE PART OF THE LARGE RINGS

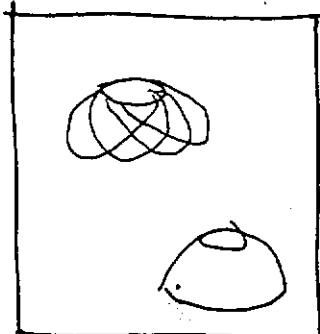


WHICH TOUCH THE SMALL RING.

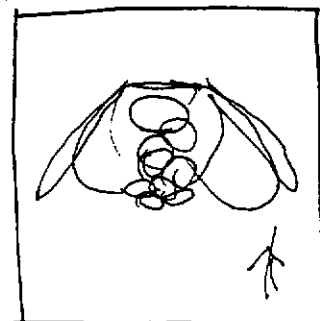


ONCE, THE "FLOWER" IS TIED TOGETHER
IN ITS CENTER,

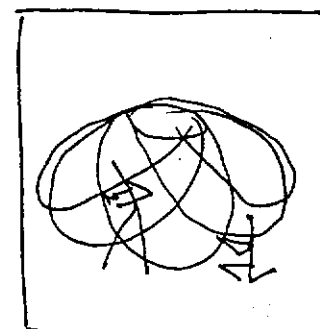
YOU SHOULD LIFT THE CENTRAL RING
UP FROM THE GROUND



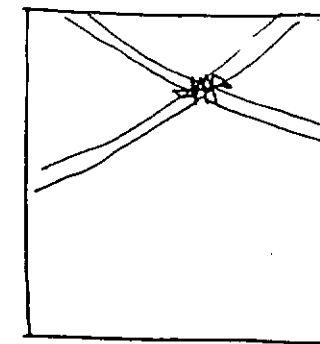
YOU SHOULD LIFT THAT RING
TO A HEIGHT,
THAT THE "FLOWER"
SHOULD FORM AN INVERSED CUP.



YOU HAVE TO KEEP
THE CENTRAL RING IN THAT POSITION
WITH A HEAP OF STONES
(FOR EXAMPLE)

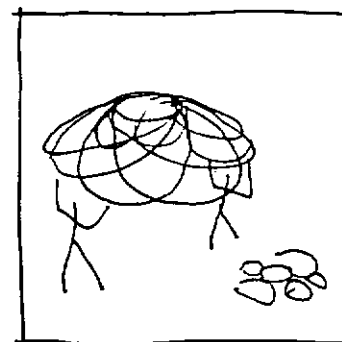


AND START TO TIE TOGETHER
THE LARGE RINGS
IN ALL THE SPOTS WHERE
THEY TOUCH EACH OTHER.

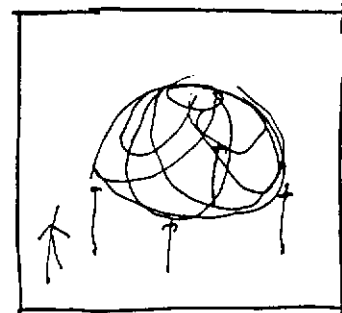


TIE THEM WELL,

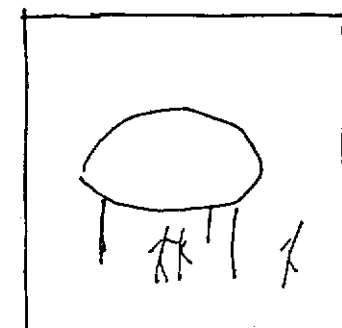
TO AVOID
THE JOINTS SLIPPING OUT OF PLACE



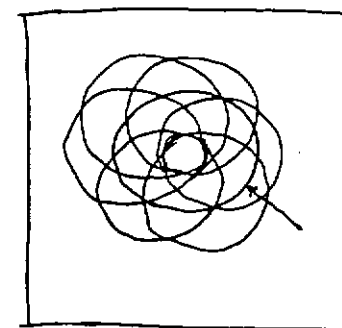
ONCE YOU HAVE FASTENED ALL THESE SPOTS
YOU CAN TAKE AWAY THE SCAFFOLDING
(THAT HEAP OF STONES):



THE DOME WILL KEEP ITS SHAPE.

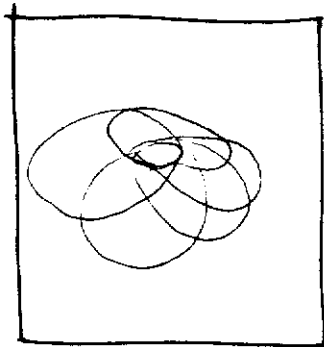


IT CAN BEAR THE ROOF-SKIN.

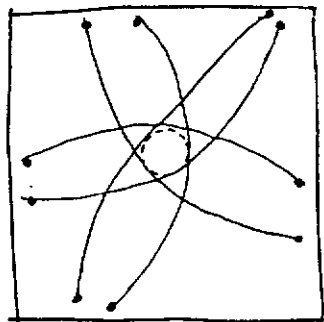


IF YOU WANT TO REINFORCE
THAT STRUCTURE,
ONE OR TWO BIG RINGS
APPLIED MID-HEIGHT

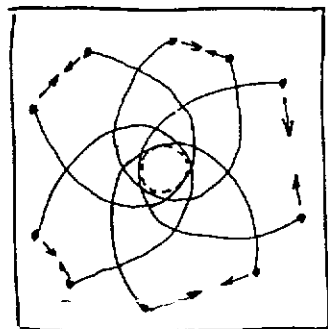
WILL DO THE JOB.



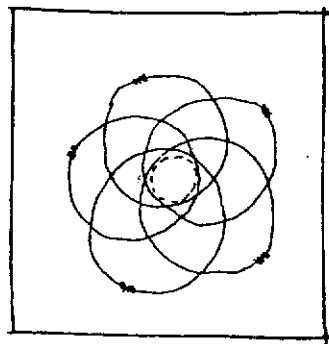
ANOTHER WAY TO MAKE
SUCH A DOME,
IS THROUGH MAKING
A "BORROMEAN" LOOP;



TO DO THIS,
START WITH (FOR EXAMPLE) 5 RODS,
PUT ON THE GROUND
AROUND A CENTRAL RING,

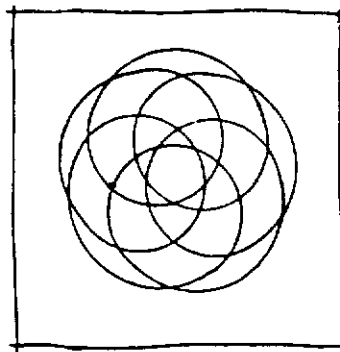


THEN BEND THEM,
MAKING THEIR ENDS MEET.

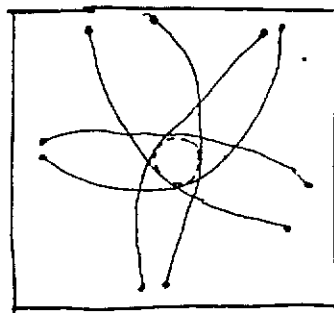


ONCE THE ENDS MET,
ON THE GROUND,
CONNECT THEM.

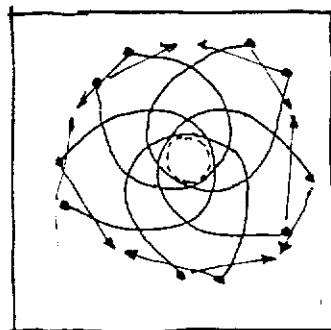
WHEN YOU LIFT FROM THE GROUND
THE CENTRAL RING,
YOU GOT A "BORROMEAN" DOME.



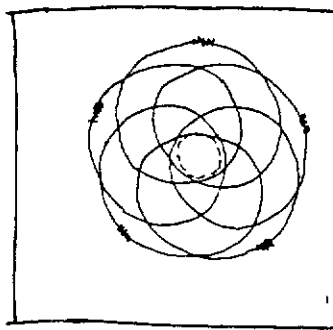
A VARIANT TO THIS
IS CALLED A "CYCLIC KNOT".



TO BUILD IT, START AGAIN
WITH 5 RODS,
PUTTING THEM AROUND THE CENTRAL RING.



BEND THEM,
AND BRING TOGETHER THE ENDS,
APPROACHING THE ENDS
OF NEIGHBOURING RODS TO MEET.



CONNECT THOSE ENDS,
LIFT THE CORE RING,

AND YOUR DOME IS READY.

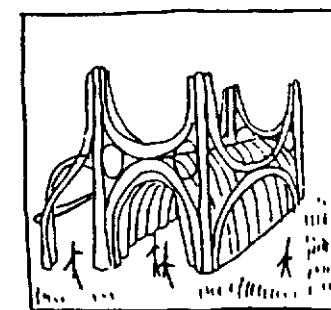


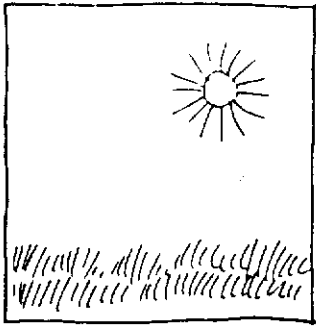
COMMUNICATION CENTRE
OF SCIENTIFIC KNOWLEDGE FOR SELF-RELIANCE



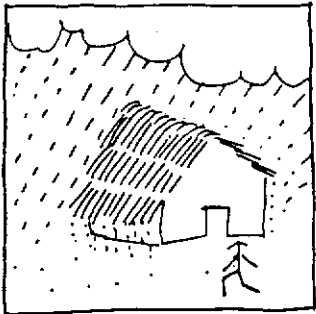
UNDER THE AUSPICES OF THE UNITED NATIONS UNIVERSITY
WITH THE PARTICIPATION OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

BUILDING WITH GRASS



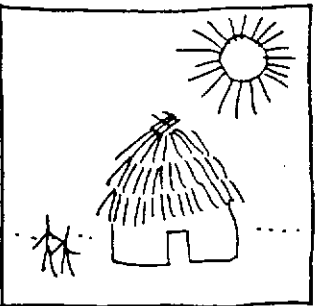


GRASS
CAN BE AN IMPORTANT BUILDING MATERIAL.



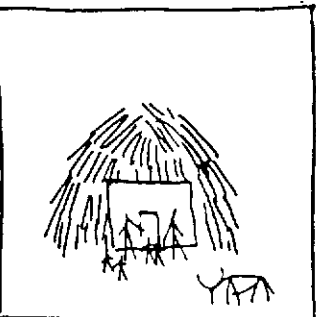
IT CAN SERVE, FIRST OF ALL,
FOR ROOFS:

GRASS BUNDLES POINTING DOWNWARDS
ALLOW THE RAINWATER TO DRIP DOWN.



GRASS CAN
A HEAT INSULATOR AS WELL,

KEEPING THE INSIDE OF THE HOUSE
COOLER, OR WARMER,
ACCORDING TO THE SEASON.



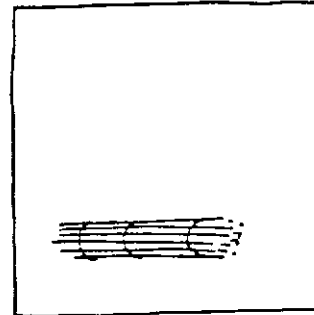
BUNDLES OF GRASS
CAN BE USED THUS AS A COAT

PROTECTING THE HOUSE OR ITS PARTS
AGAINST RAIN, TEMPERATURE AND SUNSHINE.

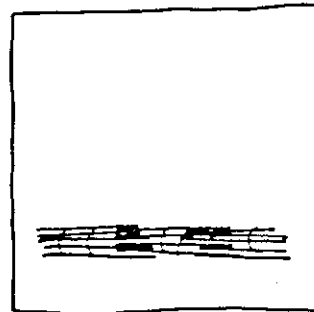


BUT
GRASS BUNDLES CAN BE STRONG ENOUGH

TO FORM THE SKELETON OF THE HOUSE.

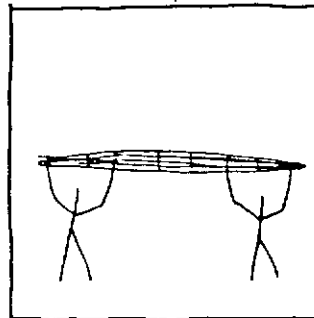


IF ONE MAKES A BUNDLE OF STRONG GRASS
TIED TOGETHER WITH STRING
(WHICH TOO CAN BE MADE OF GRASS)



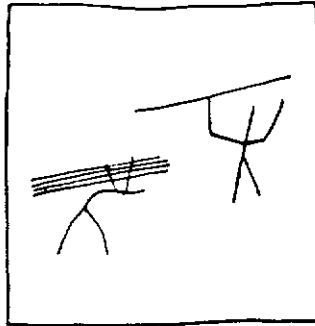
ONE CAN MAKE THEM VERY LONG
IF EACH LENGTH OF GRASS
IN THE BUNDLE

OVERLAPS THE NEXT LAYER
FOR ABOUT A THIRD OF ITS LENGTH.



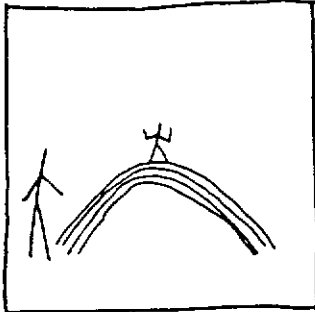
SUCH A GRASS BUNDLE
CAN BE VERY RESISTANT

IF IT IS THICK ENOUGH.

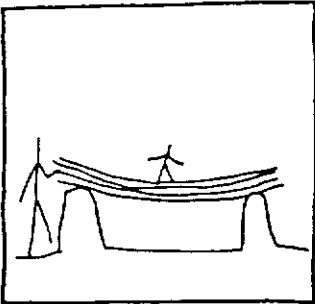


A VERY THICK GRASS BUNDLE
WORKS LIKE A BAMBOO CANE,

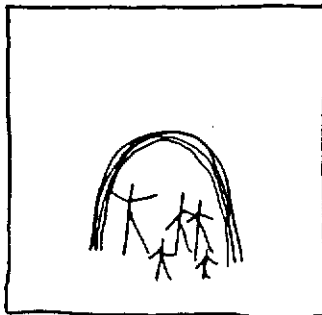
BUT THE BUNDLE
IS MUCH HEAVIER THAN THE BAMBOO.



A GRASS BUNDLE WORKS BETTER
WHEN BENT,

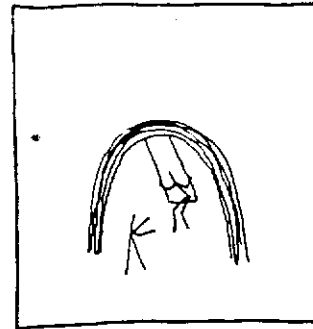


THAN IT DOES WHEN STRAIGHT.

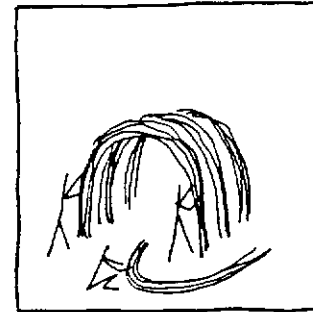


THE SIMPLEST WAY
TO USE GRASS BUNDLES

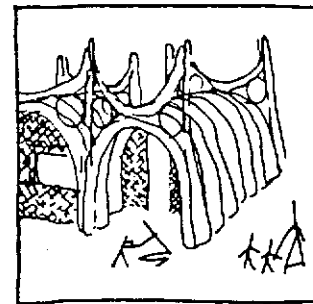
IS TO MAKE ARCHES OUT OF THEM.



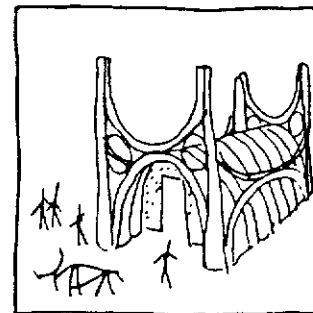
A BUNDLE - ARCH
IS QUITE RESISTANT.



PUTTING A NUMBER OF SUCH ARCHES
SIDE BY SIDE
IN A ROW

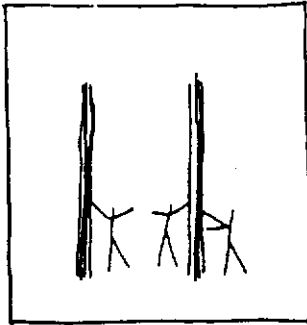


CAN MAKE QUITE A GOOD ROOF.



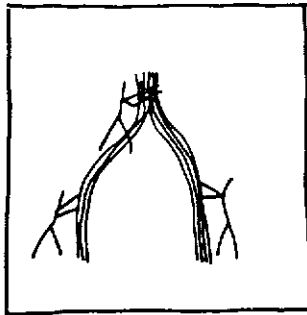
OBTAINING,
YOU HAVE TO FIX THE ARCHES
TO ONE ANOTHER

BY TRANSVERSAL BUNDLES.



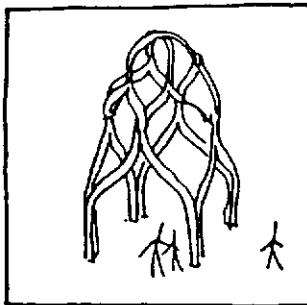
A DIFFERENT TYPE OF ARCH
CAN BE MADE

WHEN YOU MAKE STAND TWO BUNDLES OF GRASS
AT A SMALL DISTANCE BETWEEN EACH OTHER

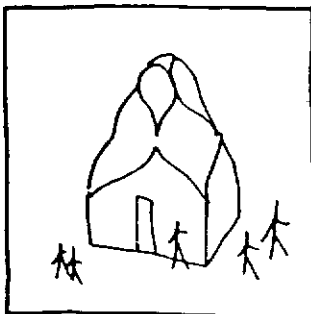


MAKING
THE UPPER ENDS MEET,

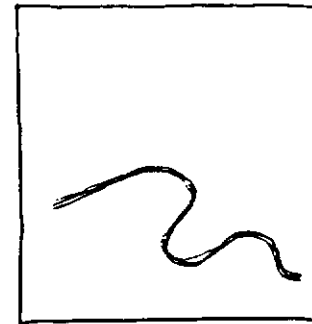
AND THEN TYING THEM TOGETHER.



IF YOU MAKE, FOR EXAMPLE,
FOUR OF SUCH ARCHES,
THEN YOU START FOUR SMALLER ONES
FROM THE POINT OF THE LOWER ONES,
AND SO ON,

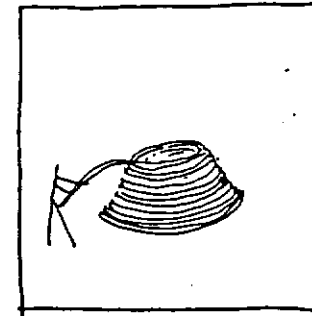


TILL YOU GET A SORT OF A CONICAL
ROOF.

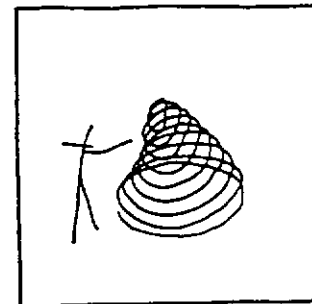


ANOTHER ROOF TYPE
CAN BE MADE OF GRASS-ROPE

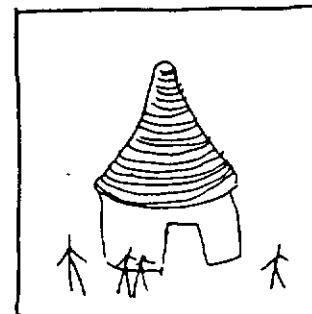
(WE CALL GRASS-ROPE
LONG THIN GRASS BUNDLES).



IF YOU COIL SUCH A GRASS-ROPE
LIKE A SNAIL'S SHELL

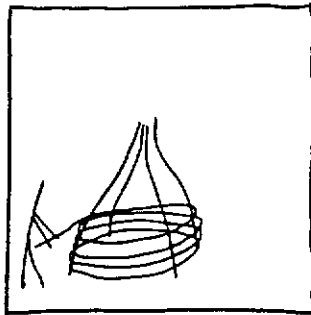


MAKING THE COILS SMALLER AND SMALLER
AS YOU GO HIGHER.

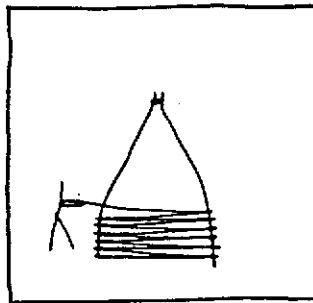


YOU GET THUS A SORT OF A DOME
OR A CONIC ROOF.

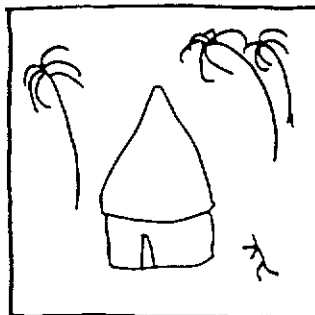
YOU SHOULD,
WHEN BUILDING SUCH A ROOF



USE SOME TWIGS, OR THIN BAMBOO,
TO DEFINE THE SHAPE
OF THE DOME:

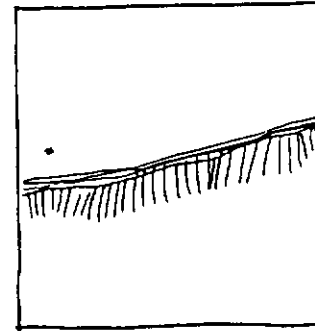


THE JOB OF COILING THE ROPE,
IS MADE EASIER

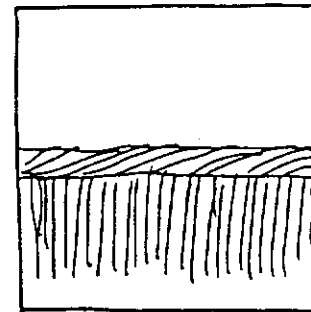


AND STRENGTHENS
THE DOME

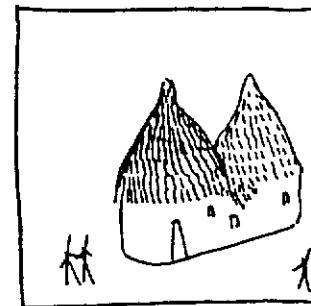
FOR RESISTING THE WIND.



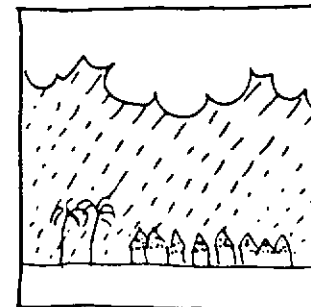
IF YOU MAKE
A "HAIRY" GRASS-ROPE



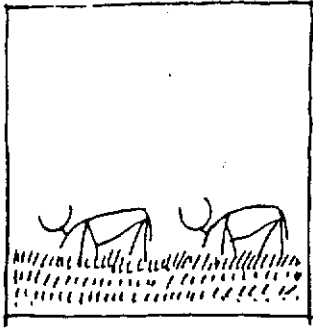
THE HAIRS OF WHICH
POINT DOWNWARDS,



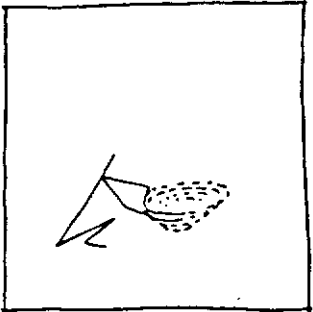
AND YOU COIL THIS HAIRY ROPE
AROUND YOUR ROOF,
CONIC OR DOMED,



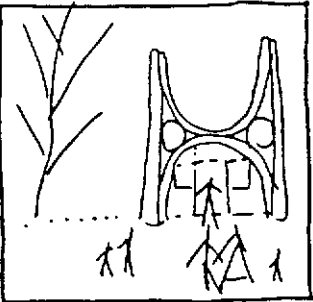
YOUR ROOF WILL BE
BETTER PROTECTED AGAINST RAIN.



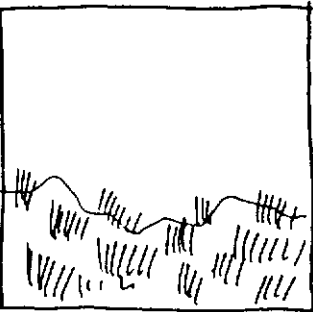
GRASS CAN BE GOOD FOOD
FOR YOUR CATTLE,



IT CAN BE A GOOD MATERIAL
TO MAKE HOUSE-HOLD USTENSILS WITH,



AND FINALLY,
IT IS A GOOD BUILDING MATERIAL.



TO MAKE GRASS GROW
ON OTHERWISE USELESS LAND

CAN PROVIDE AN IMPORTANT RESOURCE.